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INSTRUCTION BOOK

for

MODEL 355
AC-DC DIGITAL VOLTMETER

BALLANTINE LABORATORIES, INC.
BOONTON, NEW JERSEY

INSTRUCTION BOOK

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AC-DC DIGITAL VOLTMETER

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Printed in U.S.A.

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WARRANTY

Each Ballantine Laboratories, Inc. instrument, or part thereof, is warranted to be free from defects in material and workmanship. Ballantine Laboratories, Inc. obligation under this warranty is limited to repairing and replacing any instrument or part thereof, except vacuum tubes and batteries, which shall within one year after shipment to the original purchaser prove upon Ballantine Laboratories, Inc. examination to have become defective.

INSTRUCTION BOOK CONTENTS
FOR
MODEL 355 AC-DC DIGITAL VOLTMETER

Page

1. GENERAL INFORMATION 1
- 1.1 Features and Use 1
- 1.2 Some Applications of Model 355 1
- 1.3 Technical Characteristics 2

2. OPERATION 3
- 2.1 Function of Controls 3
- 2.2 Connectors 3
- 2.3 Power Connection 4
- 2.4 Starting Procedure 4
  - 2.4.1 Warmup Period 4
  - 2.4.2 Zero Adjustment 4
- 2.5 DC Voltage Measurement 4
- 2.6 AC Voltage Measurement 4
- 2.7 Possible Error Sources 5
  - 2.7.1 Readout Does Not Indicate 5
  - 2.7.2 Readout Indicates 1030 5
  - 2.7.3 Readout Indicates 9998 5
  - 2.7.4 Instrument Indicates Without Signal 5
  - 2.7.5 Loading Error 5
  - 2.7.6 Ground Current Error 5
  - 2.7.7 Magnetic and Electrostatic Fields 5
  - 2.7.8 Thermal EMF 5
  - 2.7.9 High Ripple or AC Superimposed on DC Signal 6
- 2.8 Effect of Harmonics 6
- 2.9 Measurement of Noise and Random Signals 6
- 2.10 AC Overload Considerations 6
- 2.11 DC Component of the AC Input Signal 6
- 2.12 AC Component of the DC Input Signal 6
- 2.13 High Voltage Measurement 6
- 2.14 Differential Voltage Measurement 7
  - 2.14.1 DC Measurement 7
  - 2.14.2 AC Measurement 8
- 2.15 Measuring Sources Connected to the Power Line 8
- 2.16 Input Impedance 8
  - 2.16.1 DC Mode 8
  - 2.16.2 AC Mode 8
- 2.17 Effect of Line Voltage 9
- 2.18 Use as AC to DC Converter 9
- 2.19 Use as AC Amplifier 9
- 2.20 Current Measurements 9
- 2.21 Reading Retention 9

Page

3. **CIRCUIT DESCRIPTION** 10
    3.1 Input Attenuators 10
    3.2 AC Amplifier 11
    3.3 Rectifier Circuit 11
    3.4 Filter 11
    3.5 DC Reference 11
    3.6 Servo Amplifier 11
    3.7 Motor and Counter 11
    3.8 Power Supply 11

4. **MAINTENANCE** 12
    4.1 General 12
    4.2 Recommended Maintenance 12
    4.3 Necessary Maintenance Equipment 12
    4.4 Tests Comprising the 1000 Hour Check 12
        4.4.1 Tube Test 12
        4.4.2 DC Accuracy 12
        4.4.3 AC Accuracy 12
        4.4.4 Attenuator Accuracy Test 13
        4.4.5 Noise Test 13

5. **SERVICE AND TROUBLESHOOTING** 13
    5.1 General 13
    5.2 Line Conversion 13
    5.3 Tube Replacement 13
    5.4 Fuse Replacement 13
    5.5 DC Voltage Check 13
    5.6 Signal Tracing 14
    5.7 Chopper Replacement 14
    5.8 Removal of Escutcheon Plate 14
    5.9 Attenuator Repairs 14
    5.10 AC Voltmeter Frequency Response Adjustment 15
    5.11 Attenuator Frequency Response 15
    5.12 Replacement of Indicating Lights 15
    5.13 Transistor Replacement 15
    5.14 Repair of Motor-Counter Assembly 15
    5.15 Bail Adjustment 16

6. **SHIPPING INSTRUCTIONS** 18

7. **REPLACEMENT PARTS LIST** 23

8. **MECHANICAL PARTS WHICH MAY REQUIRE REPLACEMENT** 28

ILLUSTRATIONS AND DIAGRAMS

Figure 1 Ballantine Model 355 AC-DC Digital Voltmeter IV
Figure 2 Rack Mounted Model 355 Using Model 800 Rack Mounting Kit IV
Figure 3 Location of Controls 3
Figure 4 Response and Waveform Error 6
Figure 5 Blocking a High DC Voltage 6
Figure 6 Error of Indication as Function of Input Voltage 7
Figure 7 Equivalent Input Circuit for DC Mode 8
Figure 8 Equivalent Input Circuit for AC Mode 8
Figure 9 Input Resistance Versus Frequency 8
Figure 10 Converter Linearity at 1 kHz 9
Figure 11 Simplified Circuit Diagram 10
Figure 12 Front View — Escutcheon Plate Removed 19
Figure 13 Side View of Model 355 19
Figure 14 Internal View of Model 355 20
Figure 15 Rear View of Model 355 20
Figure 16 Motor-Counter Assembly 21
Figure 17 Accessories for Model 355 22
Figure 18 Schematic of Model 355 AC-DC Digital Voltmeter .... Rear

TABLES

I AC Ripple on DC Signal 6
II Common Mode Rejection 7
III Effect of Load Impedance on DC Output 9
IV Troubleshooting Chart 17

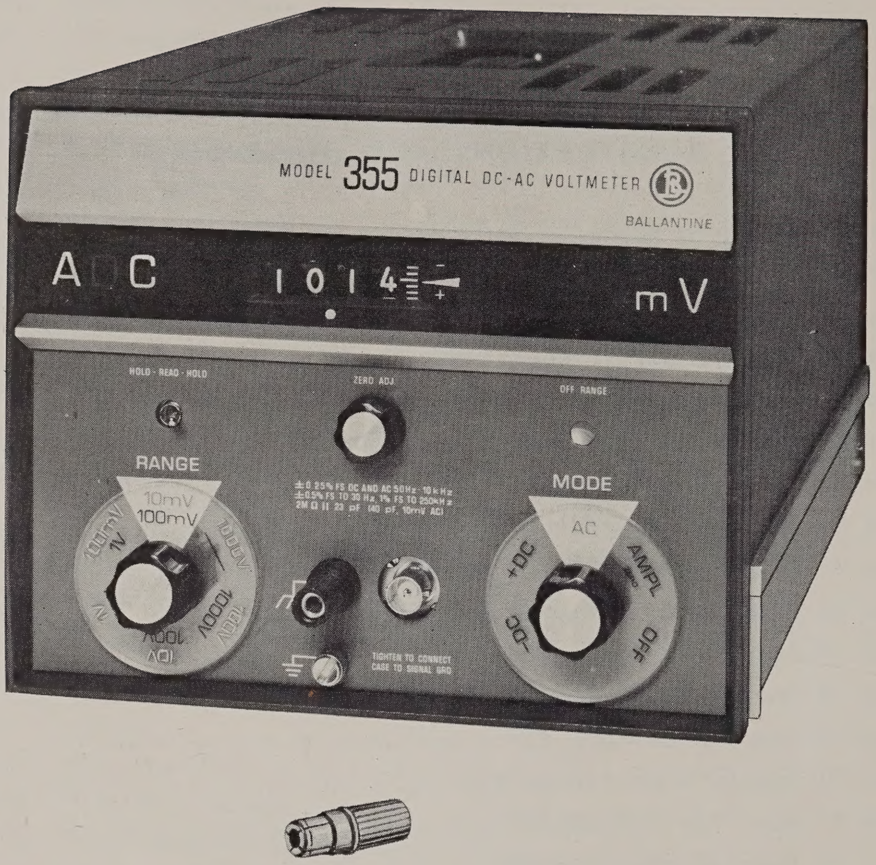


Fig. 1. Ballantine Model 355 AC-DC Digital Voltmeter

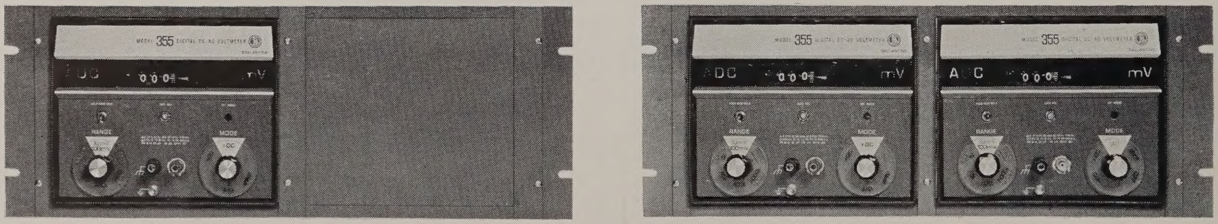


Fig. 2. Rack Mounted Model 355 Using Model 800 Rack Mounting Kit

1. GENERAL INFORMATION

1.1. Features and Use

With the Model 355 AC-DC Digital Voltmeter, Ballantine presents a compact, economical, general purpose, digital voltmeter built to the same standards of accuracy, precision and reliability that have always been associated with Ballantine voltmeters.

Featuring a servo-driven three digit counter with overranging, the Model 355 combines in one instrument many virtues of both digital and analog voltmeters. The well-lighted inline numerical readout, with illuminated decimal point, mode and range information, allows fast unconfused readings, while the turning counter wheel can follow and allow the observation of slowly varying signals. The position of the last digit may be interpolated to the nearest tenth, thus avoiding the typical ±1 digit restriction of a fully digitized display. As a further aid to unconfused readings, an over-range indicator is provided to warn of excessive input voltage or voltage of the wrong polarity.

AC voltages from below 1 mV to 1000 V can be measured over the audio range and beyond, while the most sensitive dc range of 100 mV FS covers measurements normally not possible with general purpose digital voltmeters.

For production use an auxiliary switch, either foot-operated (Model 1355) or activated by other test equipment, can be connected to terminals provided at the rear. It can be wired to hold a reading until a new measurement is to be made, or allow continuous measurements until closed. A panel-mounted switch can be similarly used to retain readings either momentarily or permanently.

The Model 355 has a coaxial BNC input, and is supplied with a Model 618 BNC-to-binding post adapter that converts the input to standard ¾ inch-spaced binding posts. Signal ground can be isolated from case ground. This feature, together with internal double-shielding, allows off ground and differential measurements with high common mode rejection.

A dc output proportional to the ac input voltage is available for recording purposes simultaneously with the digital readout, and the amplifier section of the instrument can be used separately as an ac pre-amplifier.

Special emphasis has been placed on the reliability and life of the Model 355. A balanced design using both long-life tubes and silicon semiconductors combines the advantages of both devices. Conservative operation of all electrical components further assures long life and performance. Should maintenance be required, all printed circuit boards and chassis are instantly accessible.

The Model 355 is packaged in the new compact Ballantine ½ rack modular case. Normally supplied as a portable instrument, it can be rack-mounted in minutes using the Model 800 Rack Mounting Kit.

The Model 355 can also be mounted in a HP modular enclosure without modifications.

A summary of the outstanding features of the Model 355 includes:

Accuracy and versatility in one economical package

High sensitivity for both ac and dc measurements

Direct reading digital readout — unobstructed by magnifiers, undisturbed by ambient light; voltage, mode, and decimal point clearly indicated

Over-range indication warning of excessive voltage or wrong polarity

Temperature compensated, aged Zener reference for long term stability — no batteries used as standards

Overload proof to 500 V

High impedance on all ranges

Reading retention with panel switch or external hold switch

Coaxial input convertible to binding posts, with signal ground insulated from case ground

Zero check possible without disconnecting input leads

1.2 Some Applications of Model 355

Check and alignment of generators, calibrators, voltmeters

Accurate frequency response measurement of audio amplifiers and microphones

Regulation and voltage check of ac and dc power supplies

Monitor of ac and dc supply voltages

Fast and fatigue-free production line tests of ac and dc voltages using Model 1355 foot switch

Sensitive ac to dc converter for stripchart and XY recorders

Accuracy and frequency response tests of attenuators

High resolution transfer measurements

Linearity checks on resolvers and rectifier circuits

1.3 Technical Characteristics

		AC	DC
Voltage Range		0 to 1000 V in 6 ranges	0 to 1000 V in 5 ranges
Most Sensitive Range		10.00 mV	100.0 mV
Frequency Range		30 Hz to 250 kHz	DC
Accuracy in % of Full Scale			
1 mV to 500 V	50 Hz to 10 kHz	±0.25%	±0.25%
	30 Hz to 50 Hz	±0.5%	
	10 kHz to 50 kHz	±0.5%	
	50 kHz to 250 kHz	±1%	
500 V to 1 kV	additional uncertainty after applying correction from chart	±0.25%	±0.25%

AC Indication	Average-responding calibrated in rms of a sine wave.
Maximum Balancing Time	4 s
Input Impedance	
All ranges except most sensitive	2 MΩ || 25 pF
Most sensitive range	2 MΩ || 40 pF
AC Amplifier	
Voltage gain	60 db max
Voltage output	1 V to 10 V RMS for each decade range
Source impedance	Approx. 300 Ω
Minimum load impedance	15 kΩ
Frequency response	± 1 db, 30 Hz to 250 kHz
AC-DC Converter	
Negative voltage proportional to the ac signal	100 mV to 1.0 V
Source impedance	Approx. 10 kΩ
Accuracy	
10 mV to 250 V, 50 Hz to 10 kHz	±0.5%
10 mV to 250 V, 30 Hz to 50 Hz 10 kHz to 250 kHz	±1.25%
250 V to 1000 V, 30 Hz to 250 kHz	±1.25%
Overload Capability	At least 80 db. but not to exceed 1.3 kV

AC Rejection in DC Mode	45 db, 60 Hz 40 db, 120 Hz
Common Mode Rejection (AC mode, 1 kΩ source)	>100 db, 60 Hz > 80 db, 100 kHz
Input Signal Isolation	Impedance between signal ground and case approx. 600 pF || >100 MΩ Max allowable voltage 500 V P
Warmup Time	After 10 minutes the reading will be within ±0.1% of the final value
DC Mode	Usable as indicator at once
AC Mode	Usable as indicator after 1 minute
Stability	
Line voltage	Less than 1 digit change per 10% deviation from 115 V
Recommended calibration period	AC 1000 hours of operation DC 5000 hours of operation
Maximum Ambient Temperature	50°C (122°F)
Power Requirements	115/230 V, 50 Hz to 60 Hz, 52 W
Mechanical Specifications	
Color	Charcoal Gray Case, Light Gray Panel
Dimensions (ins)	7.8 W, 6.1 H, 13.2 D
Weight (lbs)	13
Shipping wgt. (lbs)	18

2. OPERATION

2.1 Function of Controls

MODE Switch

OFF	Turns power off
AMPL (ZERO)	Instrument operates as sensitive ac amplifier with ac output on the rear of instrument — zero adjustment can be set without disconnecting input signal
AC	Instrument operates as ac voltmeter, or ac to dc converter — DC output available on rear of instrument
+DC	Instrument will indicate positive dc voltages
−DC	Instrument will indicate negative dc voltages

RANGE Selector	Selects voltage range in AC, +DC and −DC modes — changes amplifier gain in 20 db steps in AMPL (ZERO) mode
ZERO ADJ	With MODE switch in AMPL (ZERO) position this control is used to zero the voltmeter (000)
HOLD-READ-HOLD	3 position toggle switch disables the drive of the servo motor, producing reading retention — momentary retention when switch is moved to left
Ground Screw	When fully tightened, connects signal ground ⏊ to case ground ⏚

2.2 Connectors

Input	Type BNC connector for signal input — may be converted to binding posts with Ballantine Model 618 Adapter — signal ground post is connected to the low side of the BNC terminal

On the rear of the instrument are several connectors (see Figure 15). **Low terminals of the BNC connectors are connected to signal ground.**

DC Output	Type BNC connector — DC output of ac to dc converter when MODE switch is in AC position
AC Output	Type BNC connector — AC output in AMPL mode
External Hold	Appliance type receptacle for connection of external reading retention switch such as Model 1355 — **Do Not Ground**

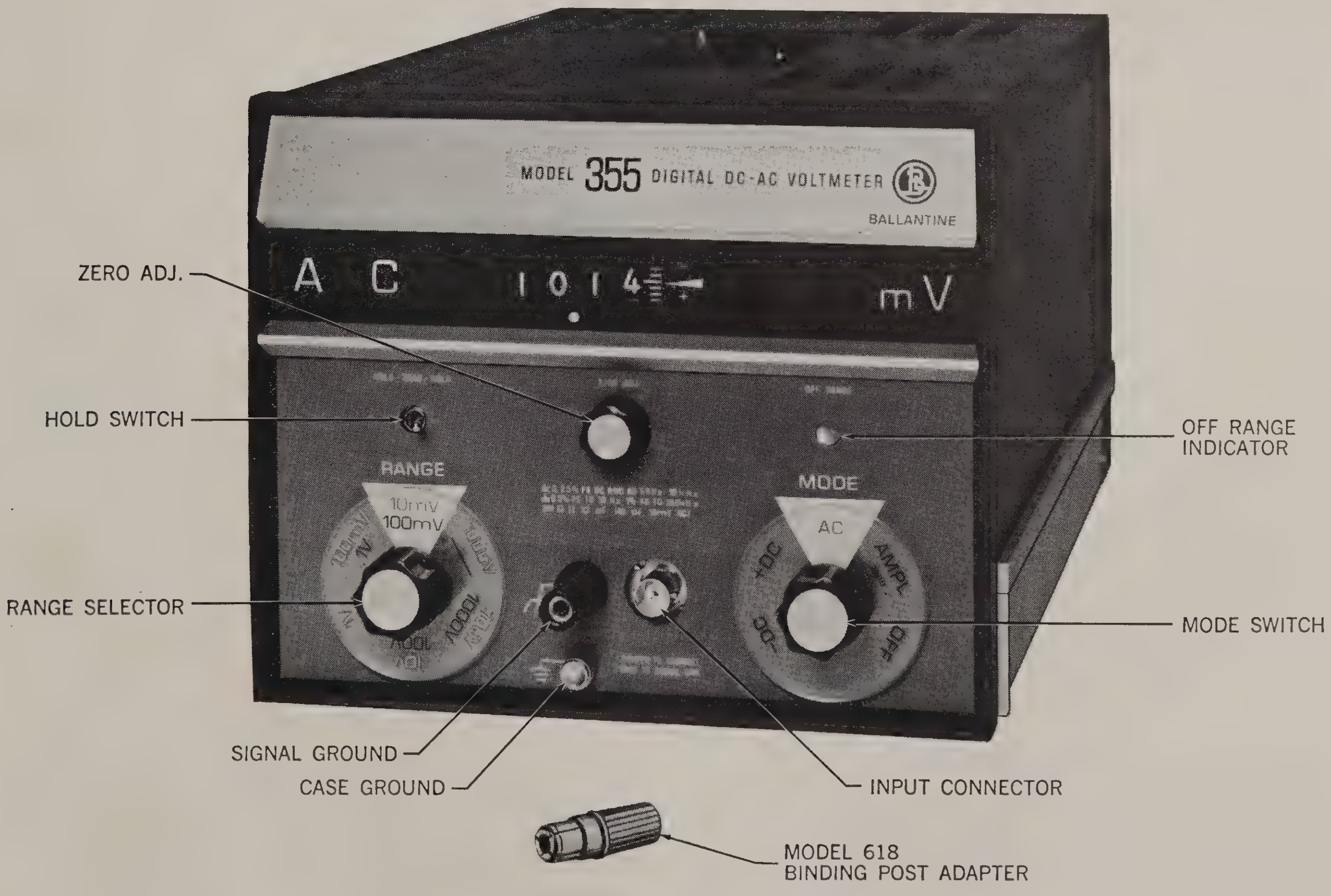


Fig. 3. Location of Controls

2.3 Power Connection

The voltmeter is supplied ready to operate on 105 V to 125 V, 50 Hz to 60 Hz power as indicated on the decal on the back of the case adjacent to the power cord.

2.3.1 Line Voltage Conversion from 115 V to 230 V or vice versa is possible. Instructions are given on the schematic diagram. For conversion to 230 V, loosen the two cover screws and remove the cover from the instrument. The conversion lugs are mounted on the board at the rear on the left side of the instrument. (See Figure 13)

Disconnect the black-red wire from terminal 1.

Disconnect the black-yellow wire from terminal 3.

Connect both wires together to terminal 2.

Replace fuse F1, 0.6 ampere, Slo-Blo by 0.3 ampere, Slo-Blo.

2.4 Starting Procedure

Insert the three-prong plug into the proper ac power outlet. Where only two-prong outlets are available, use a conversion unit. Move the MODE switch to AMPL (ZERO) position. The counter illumination light should be on. The instrument is ready for use after a short warmup period.

2.4.1 Warmup Period

The instrument is usable after approximately 30 seconds. After 10 minutes the reading will be within ±0.1 % of the final value.

For measurements of the highest accuracy or when the instrument has not been used for months or has been stored in high humidity, allow the instrument to warm up for an hour.

Two independent bails serve as instrument feet for bench use. Either can be raised and used to tilt the instrument for convenience in reading. Do **not** fold these bails completely back unless the instrument is to be rack mounted, since the regular airflow would be obstructed if the voltmeter were to be used without feet on a flat surface.

PERMIT AIR TO CIRCULATE FREELY AROUND THE INSTRUMENT AT ALL TIMES TO AVOID EXCESSIVE TEMPERATURE RISE.

2.4.2 Zero Adjustment

Before the instrument is used as a voltmeter and before measurements are to be made with highest accuracy, it is recommended that the zero adjustment be checked. For zero adjustment

Set	To
MODE switch	AMPL (ZERO)
RANGE selector	any range
HOLD-READ-HOLD switch	READ

Set the zero adjustment until the readout displays 000 ±0.3 digits. There is no need to short the input or disconnect any leads or signals. The zero adjustment can be checked at any time by moving the MODE switch to AMPL (ZERO) position. (See also 2.7.4)

If the instrument cannot be zeroed, humidity may have reached the servo amplifier printed circuit board and created spurious dc voltages. Normally the boards are sufficiently protected by a water repellent coating. However, if the instrument has been exposed to high humidity over an extended period of time, one hour of warmup should be allowed.

2.5 DC Voltage Measurement

DC voltage measurements can be made shortly after the instrument is turned on since this part of the voltmeter is fully transistorized and does not require a long warmup. For dc voltage measurement

Set	To
MODE switch	+DC or −DC
RANGE selector	1000 V or fully clockwise
HOLD switch	READ

Connect the voltmeter to the source and turn the range selector counterclockwise until an indication is obtained. While the counter is running the OFF RANGE indicator will be lit until balance is reached. If the first digit is zero, rotate the RANGE selector counterclockwise to the next lower range until a full three digit reading is displayed. An over-range of 2% is provided. This means that the meter will read correctly at least up to 1020. If the reading is any higher or if the OFF RANGE indicator is on, switch to the next higher range. In case the instrument should read 9998 and the OFF RANGE indicator light is on, the polarity selected is wrong and the MODE switch should be switched to the opposite polarity.

NOTE: NEVER USE THE READING WHEN THE OFF RANGE INDICATOR LIGHT IS ON, OR WHEN INTERNAL OR EXTERNAL HOLD IS RETAINING A PREVIOUS READING.

2.6 AC Voltage Measurement

For ac voltage measurement allow a warmup time of at least 10 minutes. Check the ZERO adjustment. To avoid ground currents and shorts, disconnect the signal ground from case ground by turning the ground screw fully counterclockwise. Use coaxial connections wherever possible. For voltage measurement

Set	To
MODE switch	AC
RANGE selector	1000 V or fully clockwise
HOLD switch	READ

Connect the voltmeter to the source and rotate the RANGE selector counterclockwise until an indication is obtained. While the counter is running, the OFF RANGE indicator will be lit until balance is reached. If the first digit is zero, rotate the RANGE selector counterclockwise to the next lower range until a full three digit reading is obtained. An overrange of 2% is provided. This means that the instrument will read correctly up to at least 1020. If the reading is any higher or if the OFF RANGE indicator light is on, switch to the next higher range.

2.7 Possible Error Sources

The causes of some obvious measuring difficulties are listed below.

2.7.1 Readout Does Not Indicate if the instrument is turned off, not connected to the power line, no signal is applied to the input, the input signal is much lower than the range selected, the MODE switch is in the wrong position, or the internal or an external reading retention switch is in HOLD position.

2.7.2 Readout Indicates 1030 if selected voltage range is too low, or if high hum is picked up by the input circuit.

2.7.3 Readout Indicates 9998 when the signal applied has the wrong polarity or the ZERO ADJ is misadjusted.

2.7.4 Instrument Indicates Without Signal when the input is not properly shielded. With a shorted input the residual noise of the ac amplifier in the AC mode produces a slight indication of 001 to 003. The accuracy of the voltage measurement is not affected by this noise as long as the voltmeter is not used below 10% of the full range, or as long as a three digit indication is obtained when a signal is applied. It is recommended that the ZERO ADJ not be used to set the indication to 000 in the AC mode.

Because of the high sensitivity and wide bandwidth of the Model 355, other measuring errors may be introduced when proper measuring techniques are not used. This can prevent the utilization of the high accuracy of the Model 355. The most common error sources are listed below. A more comprehensive analysis of errors is given in NBS Conference on Standards and Electronic Measurement paper: Techniques and Errors in High Frequency Voltage Calibration by Dr. E. Uiga and W. F. White. A copy of the paper is available from Ballantine Laboratories without charge.

2.7.5 Loading Error is caused by the input impedance of the voltmeter or the capacitance of the connecting leads. Loading makes the terminal voltage change when the voltmeter is connected. It also may detune or damp the cicuit being measured.

The error produced by the input resistance will be below 0.1% if the source resistance is below 2 kΩ.

A capacitive loading error can be minimized by using low capacitance cables or, for ac voltages above 10 V, by using the Model 1301 high voltage probe.

2.7.6 Ground Current Error is caused by ground currents of signal or power line frequency which flow through the ground connection. This current develops a voltage drop in the ground connection which is measured together with the signal. To reduce this effect the ground current should be kept to a minimum and ground impedances should be kept as low as possible. The existence of the ground currents may be determined by measuring the current with an ammeter or clip-on current probe. To reduce the ground currents, use Model 355 with signal and case grounds separated whenever possible. This is done by turning the panel ground screw fully counterclockwise.

When separation of signal and case ground is not possible, connect all equipment in the setup to a common ground at one point, using ground leads as short as possible. A substantial improvement is achieved by using a coaxial input connection. This is especially recommended for higher frequency measurements. Model 355 has a coaxial input. Use this coaxial input wherever possible. For dc measurements the input may be converted to binding posts with a Model 618 adapter.

2.7.7 Magnetic and Electrostatic Fields may cause pickup in the input leads or induce disturbances into the sensitive parts of the voltmeter. To reduce this effect, use coaxial, shielded, twisted or closely-spaced input leads. Do not place the voltmeter close to strong sources of magnetic or electrostatic fields. The most sensitive part of the voltmeter is the lower part where the low level circuitry is located.

2.7.8 Thermal EMF may cause errors in low level dc measurements if, at the voltmeter input or at the circuit under test, leads of dissimilar material are used which have junctions at different temperatures (Seebeck effect). Copper leads throughout or a uniform temperature will usually reduce these errors to an acceptable level.

2.7.9 High Ripple or AC Superimposed on DC Signal can produce errors which may make additional filtering necessary (see 2.12).

2.8 Effect of Harmonics

If the signal is distorted, harmonics of the signal may produce measurement errors. The Model 355 is average-responding but is calibrated to read the rms of a sine wave. If the source has distortion exceeding 5%, noticeable differences (up to 1.5%) between average and rms value can exist. The error depends on the amplitude, phase and frequency of the harmonics. Figure 4 shows the difference between rms and average response with second and third harmonics present.

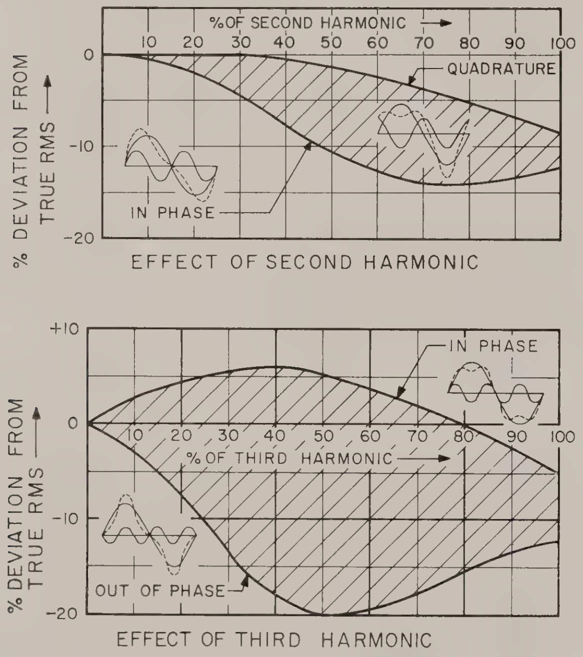


Fig. 4. Response and Waveform Error

2.9 Measurement of Noise and Random Signals

For accurate measurements of highly distorted signals or noise, the Ballantine True RMS Voltmeter Model 320A or Model 350 is recommended rather than Model 355. (See also: "How to Measure Noise with a VTVM" by Endel Uiga, Electronic Equipment Engineering, Oct. 1962, p. 87.)

2.10 AC Overload Considerations

The instrument is designed to withstand severe overload without damage to any components. The maximum ac voltage which may be applied to the instrument in the millivolt ranges is limited by the maximum allowable voltage at the grid of the first tube. For an extended time, this voltage should not exceed 35 V. However, the input tube will not be damaged by higher voltages applied for shorter periods, and tests have shown no change in instrument performance after 8 hours of overloading the 10 mV range with 500 V.

2.11 DC Component of the AC Input Signal

In AC mode the voltmeter does not measure the dc component of the signal. The maximum dc voltage which can be safely applied is 600 V. If the dc component of the signal is higher, a capacitor of at least 0.1 μF, together with a 10 megohm resistor, should be connected to the input as shown in figure 5.

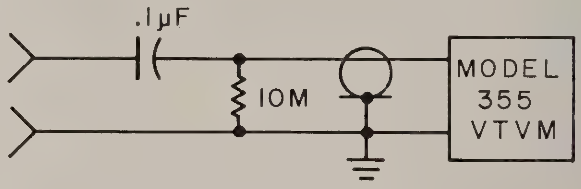


Fig. 5. Blocking a High DC Voltage

2.12 AC Component of the DC Input Signal

The input filter of the dc voltmeter will usually be sufficient to avoid errors caused by a large ac signal superimposed on the dc signal. To limit errors to 0.25% the ac component should not exceed the values given in Table I.

TABLE I

AC RIPPLE ON DC SIGNAL			
DC Voltage Range	Max AC Voltage		
	60 Hz	120 Hz	400 Hz
100 mV	0.15 V	0.15 V	0.6 V
1 V	1.5 V	1.5 V	10 V
10 V	15 V	15 V	40 V

2.13 High Voltage Measurement

If measurements above 250 V are to be made, certain precautions should be taken to protect operator and instrument.

Make sure before connecting the signal that the correct voltage range and mode have been selected.

If a large common mode voltage is to be expected, remember that all outputs and some screws on the back panel are connected to signal ground. Separate signal and case ground, but make sure that the case is eventually grounded.

At voltages above 300 V the accuracy of the dc and ac voltmeter as well as the ac to dc converter and amplifier will be less than for lower voltages. This accuracy degradation is the result of a temperature rise in the attenuator R3. Since the power dissipated will not raise its temperature instantaneously, some drift will be noted before a stable indication or output occurs. Accuracy correction for this effect can be made by using figure 6 showing the error in percent of reading and digits as a function of the voltage applied. To obtain the true input voltage subtract the error shown in figure 6 from the indicated input voltage.

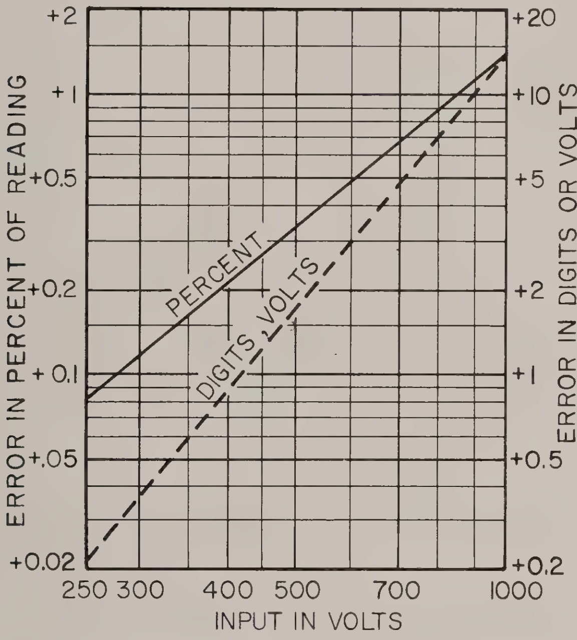


Fig. 6. Error of Indication as Function of the Input Voltage

This correction applies to both ac and dc readings as well as to converter and amplifier modes.

If ac voltages higher than 1000 V are to be measured the Ballantine Model 1301 is recommended. This capacitive divider extends the range of the Model 355 to 10 kV.

If dc voltages higher than 1000 V are to be measured external dividers should be used. Do not use the unmarked dc range, even though it provides an additional 10:1 extension, since voltage ratings of resistors, switches and capacitors will be exceeded.

2.14 Differential Voltage Measurement

2.14.1 DC Measurement

The Model 355 signal and case grounds are separated. Internal shields are used to prevent a common mode voltage appearing between case and signal ground that could influence the sensitive parts of the voltmeter. However, **the low side of the outputs are connected to signal ground.** Therefore, when making differential voltage measurements, disconnect any leads connected to these outputs unless special precautions are taken to prevent shock hazards and external shorts between signal ground and case ground. To separate signal and case grounds the grounding screw on the front panel of the Model 355 should be fully counterclockwise. The maximum common mode voltage which can be tolerated between signal and case ground is 500 V peak.

The common mode rejection depends on the frequency and amplitude of the common signal as well as on the source impedance of the signal circuit. If a common mode voltage of 25 V is introduced between signal ground and case ground, its effect on the measured signal can be noted. On the most sensitive range and for a signal with 1 kΩ source resistance the common mode rejection is shown in Table II.

TABLE II

COMMON MODE REJECTION FOR 1 kΩ SOURCE							
Common Mode Signal 25 V at	DC	15 Hz	60 Hz	120 Hz	1 kHz	100 kHz	1 MHz
Common Mode Rejection AC MODE	>120 db	110 db	110 db	110 db	110 db	100 db	>100 db
DC MODE	>120 db	>120 db	>120 db	120 db	120 db	100 db	>100 db

In DC mode the impedances at balance are approximately as follows:

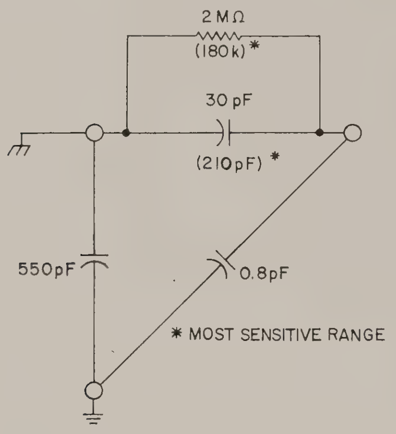


Fig. 7. Equivalent Input Circuit for DC Mode as seen by a 1 kHz Signal

2.14.2 AC Measurement

Precautions mentioned under DC measurement (2.14.1) should be observed. The common mode rejection depends on frequency and amplitude of the common mode signal as well as the source impedance of the signal circuit. For a source with 1 kΩ source resistance the common mode rejection is shown in Table II. Equivalent input circuits are shown in figure 8. All measurements were made at 1 kc. While the capacitive component of the input impedance stays fairly constant the resistive component changes with frequency as shown in figure 9.

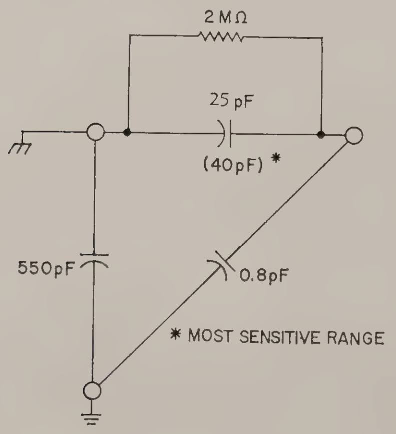


Fig. 8. Equivalent Input Circuit for AC Mode

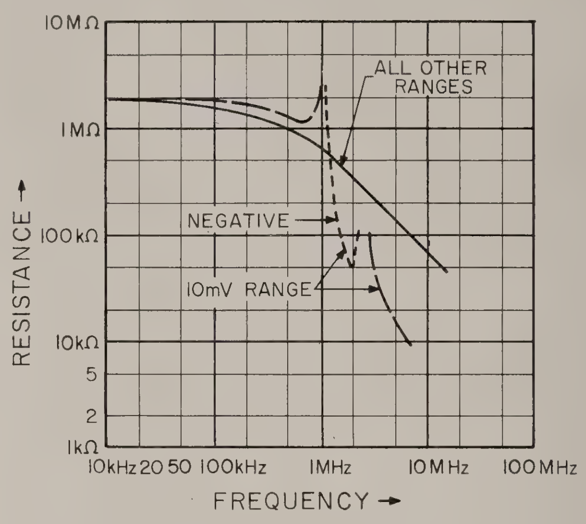


Fig. 9. Input Resistance Versus Frequency (AC Mode)

2.15 Measuring Sources Connected to the Power Line

When measuring sources which have a connection to the power line, the third prong of the line cord has to be considered. It is connected to the case and, if the ground screw on the front panel is tightened, to the signal ground. In case the low terminal of the source has any potential to the ground, a ground current may flow through the chassis if it is grounded. This can disturb the measurement or, in extreme cases, cause short circuits. This condition of measurement should be avoided. See paragraph 2.14.

2.16 Input Impedance

2.16.1 DC Mode

For dc the input resistance is 2 MΩ on all ranges, except the most sensitive range. Here the input resistance will be approximately 650 kΩ if off balance, increasing to 2 MΩ when balance is reached. For the three terminal input the equivalent circuit at 1 kHz is shown in figure 7.

2.16.2 AC Mode

The input impedance of the instrument in ac mode depends on the range selector setting and on the frequency of the signal. At dc the input resistance is approximately infinite. At low frequencies and the 10 mV range the input impedance is represented by 2 MΩ shunted by 40 pF; on all other ranges by 2 MΩ shunted by 25 pF. The capacitive component changes very little with frequency. The change of the resistive component with frequency is shown in figure 9. A simplified equivalent circuit for the three terminal input is shown in figure 8.

2.17 Effect of Line Voltage

The instrument is operative with line voltages of 100 V to 130 V or 200 V to 260 V. Line voltage variations from the specified operating voltage 115 V or 230 V affect the accuracy of the instrument at midband frequencies or at dc typically less than 0.5 digits per 10% line voltage change.

If the line voltage drops below 100 V or exceeds 130 V, a large amount of jitter may be noticeable. The instrument should not be used under these conditions. (See also adjustment of R102, 4.4.2.) Variations in the line frequency (45 to 65 Hz) will normally not affect the operation of the instrument.

2.18 Use as AC to DC Converter

By using the dc output accessible in the rear of the instrument the Model 355 can be operated as an accurate ac to dc converter. The dc output voltage is available at the BNC output connector any time the instrument is in AC MODE. For a full range indication (1000) the available dc voltage is −1.0 V ±0.5%. This voltage will be proportional to the ac signal down to an output voltage of −100 mV. The 10 to 1 range of ac to dc conversion may be exceeded by 10% at each end without affecting the linearity. Change the range selector if the limits are exceeded.

Figure 10 shows typical deviations from true linear conversion and can be used to correct for linearity errors.

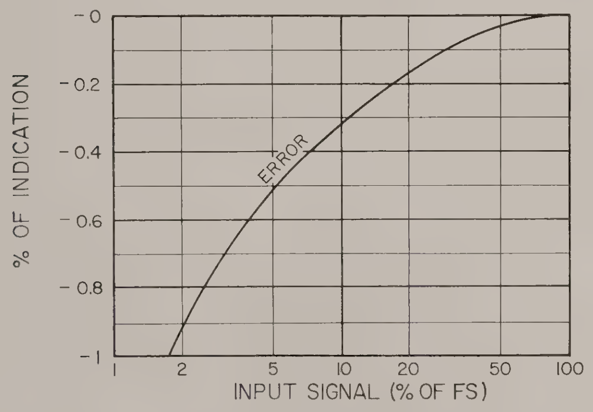


Fig. 10. Converter Linearity at 1 kHz

For some devices connected to the dc output, the ripple of the dc voltage may prove excessive at low frequencies. The ripple can be reduced by connecting a capacitor (not to exceed 30 μF) across the input of the monitoring device. However, this capacitor may accumulate a charge under open circuit conditions. If it discharges suddenly through the monitoring device (i.e., moving coil meter) damage could result to this device.

The dc output impedance of the Model 355 is approximately 10 kΩ. Table III shows the loading errors for some typical load impedances.

TABLE III

EFFECT OF LOAD IMPEDANCE ON DC OUTPUT

Load Impedance	1 MΩ	2 MΩ	5 MΩ	10 MΩ
Drop of DC Output Voltage	1%	0.5%	0.2%	0.1%

2.19 Use as AC Amplifier

The Model 355 may be used as a stable, wideband amplifier.

Set	To
Function Switch	AMPL
Range Selector	According to the Input Voltage or Desired Gain
Output	BNC Connector in Rear

The gain of the amplifier is determined by the setting of the range selector and the load impedance. With the range selector set to 10 mV FS position, the maximum gain into an unloaded output is 1000, or 60 db. Switching to higher voltage ranges will decrease the gain in 20 db steps. The voltage at the amplifier output is 10 V for an input signal which produces a full range indication in the voltmeter mode. The next higher voltage range should be selected if the voltmeter reads above scale, in order to avoid overloading the amplifier. The lowest output voltage is limited by the noise output, which is in the order of 10 mV.

2.20 Current Measurements

Using Ballantine Series 600 Precision Shunt Resistors, ac or dc currents from 10 μA to 10 A can be measured. These and other accessories are described in the general Ballantine catalog.

2.21 Reading Retention

The 3-position toggle switch on the front panel of the instrument, marked HOLD-READ-HOLD is used for reading retention. Moving the switch to the left disables the motor drive as long as the switch is held in this position. Thus a momentary reading retention is obtained. If the toggle switch is moved to the right the switch will hold the reading permanently until the switch is returned to its center READ position.

This switch should be used

- as standby switch to avoid noise and unnecessary wear of the readout display and precision potentiometer
- if series of measurements are to be made, all voltages being of approximately equal magnitude
- if stability tests are being conducted, and it is advantageous to observe the change from the previous reading
- if the instrument is being used as an ac to dc converter and there is no need for simultaneous readout.

In addition, and especially for production line measurements or in connection with a measuring system, an external switch can be connected at the rear of the Model 355 to the appliance type connector marked EXTERNAL HOLD.

If a foot switch such as Ballantine Model 1355 is wired to this connector in such a way that its contacts are **normally closed,** the voltmeter will read only if the the foot switch is depressed ("Press to read" switch). This type of connection has the most applications. Similarly, if the contacts selected are **normally open** the voltmeter will stop reading the moment the switch is activated.

If an external switch is being used, the panel HOLD switch, which is in parallel with it, should be in the READ position.

Any external switch used should be able to carry at least 250 mA ac current at 10 V.

3. CIRCUIT DESCRIPTION

The basic voltmeter circuits are shown on a simplified diagram, figure 11. A complete schematic and a replacement parts list are at the end of the instruction book. The basic parts of the voltmeter are:

3.1 Input Attenuators

The signal is fed from the front panel BNC connector to the input attenuators. If the instrument is used in AC MODE a dc blocking capacitor is used. Three independent dividers are used. In the most sensitive range the signal passes without attenuation. 20 db attenuation is provided on the following range (100 mV ac, 1 V dc) by R1 and R5. For frequencies above 15 kHz the capacitors C2 and C6 take over and determine the attenuation. Similarly, in the 1 V ac or 10 V dc range R2 — C4, R6 — C7 produce 40 db attenuation. In the three remaining ranges the lower half of the attenuator is tapped and 60, 80 and 100 db attenuation is obtained through R3 — C5 and R7, R8, R9 paralleled by C8. The last (100 db) position is used in AC MODE only. The small capacitor C9 corrects for the capacitive load of the amplifier input. All resistors are of the hermetically-sealed type and carefully matched in resistance and temperature coefficient.

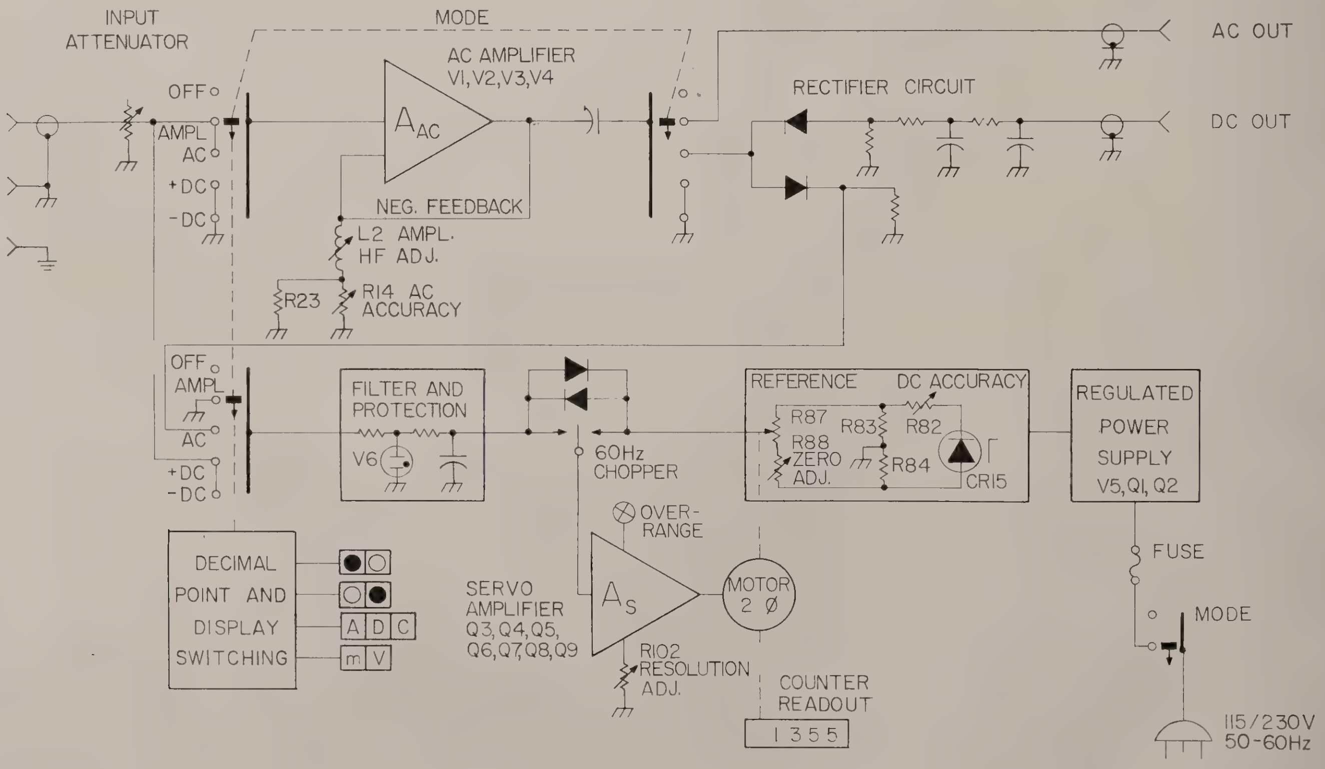


Fig. 11. Simplified Circuit Diagram

3.2 AC Amplifier

The amplifier is a four stage feedback amplifier with tubes V1, V2, V3 and V4. In midband each tube is stabilized by at least 8 db of local feedback in addition to approximately 32 db of overall loop feedback. The gain of the amplifier is adjusted by R14 and R18. L2 adjusts the high frequency response.

3.3 Rectifier Circuit

The signal rectifier consists of a dc blocking capacitor C26 and signal rectifier diodes CR1 and CR2, connected to the plate of V4 through the mode switch S2. The circuit is average-responding. The positive dc signal is divided by R51 and R50 and measured by the dc voltmeter section. The negative dc signal is fed to the dc output through a filter network consisting of C33, 34, 35 and R56, 57.

3.4 Filter

If the mode switch S2 is in the dc position the output of the input attenuator is fed into the input of the servo voltmeter through a filter. This low pass filter is of the notch type and provides maximum damping between 50 Hz and 60 Hz. V6 is a small neon lamp and protects the circuit in case the wrong voltage range or mode is selected. The output of this filter is compared to an adjustable reference voltage by a 50 to 60 Hz mechanical chopper. The chopper contacts are protected by CR16 and CR17.

3.5 DC Reference

The heart of the dc reference is a temperature compensated zener diode CR15 producing approximately 9 V DC. It is fed from a fixed current source with transistor Q2 and zener diode CR14. R66 has a temperature coefficient, which compensates for temperature effects of Q2 and CR14. The fixed reference voltage is reversed in the mode switch S2 for −DC voltage measurements. A divider (R81, R82 and R83) divides the voltage down to 100 mV DC. This voltage is further divided in the motor driven 10 turn potentiometer. The motor adjusts the dc output voltage on R87 until it is equal to the dc input signal appearing on the output of the filter. R88 is a zero adjustment and nulls out potentiometer end resistance and spurious dc voltages. R85 can be used to equalize the zero for positive and negative dc voltage measurements.

If the system is unbalanced, the reference voltage on R87 will not be equal to the input signal. The chopper comparing the two voltages will then produce a 60 Hz square wave ac signal varying in phase depending on whether the input signal is larger or smaller than the reference voltage. This difference ac signal is amplified in the servo amplifier.

3.6 Servo Amplifier

The servo amplifier is a high gain seven-stage transistor amplifier. Transistors Q3 and Q4 are direct coupled and provide a high input impedance in a cascaded emitter-follower configuration. The following three stages, Q5, Q6 and Q7, produce a voltage gain of approximately 80 db (10,000). The gain is adjustable by R102 which increases or decreases the amount of local feedback at Q5. Driver and power transistors Q8 and Q9 are again direct coupled. The collector load of Q9 is the servo motor. C71 and C72 neutralize the inductive load. If the difference signal is large enough, corresponding to an off range condition, indicator I1 will light.

3.7 Motor and Counter

The output of the servo amplifier drives one winding of the induction motor (control winding). The other winding is excited by the reference voltage. Depending on the phase of the amplified difference signal on the control winding, the motor will turn right or left. The motor is coupled with 10.3:1 reduction to a precision 10-turn potentiometer. If chopper, potentiometer and motor are phased correctly, the difference signal produced by the chopper will decrease until balance is achieved or the end stop of the 10-turn potentiometer is reached.

A turns counter is connected to the motor shaft to obtain a digital readout that is a function of the setting of the multiturn potentiometer.

3.8 Power Supply

The power supply provides several stabilized and unstabilized supply voltages.

300 V AC is used for mode and decimal point display. This 300 V is also rectified and stabilized with an OA2 glow discharge regulator (V5) for the 150 V DC as B+ supply of the ac amplifier. The filaments of all tubes are series connected and driven from a constant current source using a high power transistor Q1 as regulator and the zener diode CR13 as reference. The filament current may be adjusted with the combined resistors R62 and R63. Any one or all filaments can be short circuited without damaging the circuit.

A similar current source is used to drive the temperature compensated reference element CR15, with R65 added to improve the regulation.

The dc supply voltage for the servo amplifier is derived from a bridge rectifier circuit. The ac supply voltage drives the motor reference winding and, through phasing capacitors C44 and C45, the chopper as well. The value of these capacitors is critical since it determines the voltage on the chopper drive.

4. MAINTENANCE

4.1 General

The Model 355 is designed for extended, trouble-free service. All components are operated well below ratings. Operation for more than 3000 hours may be anticipated without need for component or tube changes.

The purpose of periodic maintenance procedures is to assure the specified accuracy, check the condition of the voltmeter and detect and replace deteriorated tubes or components before they have an appreciable effect on the instrument's performance. The procedure is designed not only to measure and correct voltmeter performance at the time of test, but to foresee the possible troubles and guarantee the instrument accuracy through the next maintenance period.

4.2 Recommended Maintenance

Maintenance should be performed every 1000 hours of operation, corresponding to a semi-annual check if the instrument is being used 8 hours every working day.

Because of the instrument's high accuracy, calibration equipment may not always be available to conduct a complete recalibration. If this is the case, maintenance should be limited to a check of the dc accuracy (4.4.2) and the instrument returned to Ballantine Laboratories for a complete calibration.

4.3 Necessary Maintenance Equipment

4.3.1 Stable, calibrated dc voltage source, adjustable from 100 mV to 100 V. Accuracy 0.1 % or better. Source impedance below 1 kΩ. Ballantine Model 421 Precision Voltage Calibrator can be used.

4.3.2 Stable, calibrated ac voltage source, frequency between 400 Hz and 1 kHz voltage adjustable from 10 mV to 100 V. Voltage calibration accuracy ±0.1 % or better. Ballantine Model 421 Precision Voltage Calibrator is recommended.

4.3.3 DC Voltmeter — range 0 to 500 V, accuracy ±3%, input resistance 10 MΩ or higher. Ballantine Model 365 is recommended.

4.3.4. Tube tester to measure tube transconductance and grid current.

4.4 1000 Hour Tests

4.4.1 Tube Test

Loosen the two Phillips head screws on the top of the instrument and remove the cover. Remove all four 6AU6A amplifier tubes. Identify all tubes so that they can be returned to their original sockets. Check the tubes for transconductance and grid current. Replace tubes if the transconductance is below the minimum limit specified by the manufacturer. **Tube replacement does not require a frequency response test.** Replace the cover. Leave screws off temporarily.

4.4.2 DC Accuracy Test

Allow the instrument (with cover on) to warm up for at least 30 minutes. Check the zero adjustment (see 2.4.2). Feed in an accurate dc signal 100 mV ±0.1 %.

Set	To
MODE Switch	+DC
RANGE Selector	100 mV (most sensitive)
HOLD Switch	READ

The readout should indicate 100.0 mV ±1 digit. Check the resolution. Approach the reading from below and above 100 mV. Note the difference in the two readings. If the difference exceeds 1 digit (.1 %) readjust the **Resolution Adjustment R102** accessible through the bottom of the instrument.

If this control is set too high an excessive amount of jitter may be noticed because of the limited resolution of the multiturn potentiometer and the noise of the servo amplifier. To avoid unnecessary wear of the readout, use the minimum resolution needed for repeatable readings.

If the average of the two readings deviates from 100.0 mV by more than 1 digit readjust the **DC Accuracy Adjustment R82.** This control is accessible after removal of the cover. It is located on the left side of the instrument on a small printed circuit board. A small Phillips head screwdriver is recommended for the adjustment. Replace the cover and recheck the adjustment after 10 minutes.

4.4.3 AC Accuracy Test

After warmup and dc accuracy test, the ac accuracy can be checked.

Set	To
MODE Switch	AC
RANGE Selector	10 mV (most sensitive)
HOLD Switch	READ

Using coaxial connections, feed in an accurate 400 Hz to 1 kHz signal of 10 mV ±0.1 %. The instrument should indicate 10.00 mV ±0.2 %. If the reading deviates by more than 2 digits, readjust the **AC Accuracy Adjustment R14.** This control is accessible after removal of the cover. It is located on the left side of the instrument on a small printed circuit board. A screwdriver can be used for adjustment or the control can be turned by hand. Set the control until the counter indicates 10.00 mV ±½ digit. Recheck the adjustment after replacing the cover and allowing an additional warmup.

4.4.4 Attenuator Accuracy Test

The use of Ballantine 421 is recommended. If this instrument is not available, the test can be conducted using a voltage source between 400 Hz and 1 kHz and an accurate ratio transformer. Allow sufficient warmup time for both instruments. Feed a 10 mV rms signal into the Model 355.

Set	To
MODE Switch	AC
RANGE Selector	10 mV (most sensitive)
HOLD Switch	READ

Note the indication. Check all other ranges at full range. For the highest voltage range a downrange reading may be sufficient. All readings should be within 2 digits. If the error spread is higher, V1 may be drawing grid current or one or more attenuator resistors may have shifted. In this case the instrument should be repaired according to paragraph 5.9.

4.4.5 Noise Test

Set	To
MODE Switch	AC
RANGE Selector	1000 V
HOLD Switch	HOLD

Using a dc voltmeter, measure the dc voltage on the converter (dc) output at the rear of the instrument. This is the type BNC connector marked "DC". The dc voltage should be between −1.5 and −2.5 mV. If a sensitive dc voltmeter is not available, the noise can also be checked in amplifier mode with a sensitive ac voltmeter connected to the ac output. AC noise is typically 10 mV. (See also 2.7.4 and 4.4.2.) If the noise is excessive the most likely cause is the input tube V1.

5. SERVICE AND TROUBLESHOOTING

5.1 General

In case of voltmeter malfunction, servicing by the user is feasible, provided skilled personnel and recommended equipment are available and the procedures outlined below are followed. However, it should be pointed out that described procedures are only simplified outlines of service and calibration. Refined service and comprehensive calibration require special equipment which may not be available to the user. Therefore, if this is the case, or if trouble develops which cannot be corrected by the simplified methods outlined here, or when most accurate calibration of the voltmeter is needed, it is recommended that the voltmeter be returned to Ballantine Laboratories for service and recalibration. The instrument should in all cases be preceded by a letter giving the exact nature and symptoms of the trouble (see Section 6 for shipping instructions).

WARNING: When the instrument is operated without the case, the danger of electric shock exists. USE EXTREME CARE. The highest voltages are 300 V AC, 350 V DC.

5.2 Line Voltage Conversion

Instructions are also given on the schematic diagram at the end of this instruction book.

For conversion to 230 V:

Disconnect black-red wire from terminal 1 and black-yellow wire from terminal 3. Connect both together to terminal 2.

Replace fuse F1, 0.6 ampere, Slo-Blo, with a 0.3 ampere Slo-Blo.

5.3 Tube Replacement

Replacement can be made with any tubes which meet manufacturer's specifications. No selection is needed. When several tubes are changed, and the transconductance of all changed tubes happens to be abnormally high or low, the voltmeter sensitivity may change slightly (up to 0.2%). This change may be corrected by setting the ac accuracy adjustment according to 4.4.2.

When V1 has been changed, check for noise (see 4.4.5). Do not replace tubes which check normal.

5.4 Fuse Replacement

To replace fuse, unscrew the fuseholder cap on the rear panel and pull out the fuse. For replacement, use:

For 115 V operation, 0.6 A Slo-Blo ¼" x 1 ¼" fuse
For 230 V operation, 0.3 A Slo-Blo ¼" x 1 ¼" fuse

Investigate and correct the cause of fuse failure before replacing the fuse. At 115 V the voltmeter normally draws 430 mA line current.

5.5 DC Voltage Check is needed when voltmeter shows a malfunction which cannot be corrected by tube replacement. Determine from the block diagram the section of the instrument involved.

5.5.1 For the dc voltage check, remove the cover, remove the L-shield on tube V1 socket or the shield on top of the servo amplifier. Connect the voltmeter to 115 V ±3 V power, short the input terminals and

Set	To
MODE Switch	AMPL
RANGE Selector	10 mV

5.5.2 Measure the voltages on all tubes and transistors with a dc voltmeter. Compare the result with the values given on schematic. They should agree to ±15%. If any voltage is outside the 15% limit, check the associated tube, transistor and components until the reason for the deviation is found.

5.5.3 Check the grid current and biases of the tubes by measuring the grid voltages. The dc voltages on the control grids are typically below 50 mV.

Replace all shields after the trouble is located.

5.6 Signal Tracing

Signal tracing is recommended when a voltmeter malfunction shows up in AC mode only and cannot be found by dc voltage check. For signal tracing, remove the case, connect the voltmeter to 115 V power, apply 10 mV ±1%, 1 kc signal to the input.

Set	To
MODE Switch	AMPL
RANGE Selector	10 mV

Use a sensitive ac voltmeter to measure the pin voltages. They should agree to within ±5% of the values marked on the schematic.

CHECK ALL VOLTAGES WITHIN THE AC AMPLIFIER when measuring ac voltages because, in a feedback amplifier, trouble in one stage may affect the ac voltages elsewhere in the circuit. Therefore, location of an incorrect ac level does not necessarily pinpoint a trouble location. Because of negative feedback the ac voltages are usually high in the stages preceding the actual trouble spot.

If the signal voltage measures normal at the ac amplifier output but incorrect indication is observed, check the rectifier circuit (CR1 and CR2) and the dc output.

5.7 Chopper Replacement

The chopper used in the Model 355 is the hermetically sealed, plug-in type and is relatively uncritical. It is used to switch the servo-amplifier input alternately to reference and unknown voltage. Replacing the unit makes a check of the zero adjustment and resolution necessary.

A defective chopper may produce any of the following symptoms:

No dc or ac reading

Large jitter in DC mode at all voltages

More than 2 digits discrepancy between +DC and —DC measurements

Slow running display, poor resolution

5.8 Removal of the Escutcheon Plate is required when attenuator adjustments have to be made, or if the motor assembly is to be exchanged.

For removal of the escutcheon plate:

Turn OFF The Instrument.

Remove all 3 knobs and 2 dials.

Take off the cover.

Remove the two #4 flat head screws on the right and left top corners of the front frame, and then remove the two #4 binder head screws on the bottom of the instrument.

Unplug the 9 pin connector supplying power to the escutcheon plate. **Danger** exists if instrument has not been turned off.

Pull out the escutcheon plate.

The locations of the controls underneath the escutcheon plate are marked on the photograph (fig. 12) at the end of this instruction book.

5.9 Repairs on Attenuators

The resistors used in the attenuators have been selected and factory-matched for resistance value and temperature coefficient. If the dc resistance measurement of R1 to R9, except for R4, shows deviations greater than 1% and the attenuator has been found to be in error, we recommend sending the instrument back to the factory for repair.

If the instrument has been out of use for an extended time, and/or stored in an atmosphere containing sulphur, the range selector can become intermittent and produce shifts in indication when tapped. This condition can usually be overcome by rotating the switch several times, since its contacts are self-cleaning. Otherwise, the switch contacts should be carefully cleaned using alcohol or any recommended contact cleaner.

Often mistaken as an intermittent range selector switch is a condition which produces sudden "kicks" on the meter when the range selector is rotated. Most of the time this is caused by grid current in V1 or by excessive leakage current of C1 rather than by a defective switch.

5.10 Voltmeter Frequency Response Adjustment

Since the ac amplifier frequency response extends well beyond its specified limits and generous amounts of local and overall feedback are used to stabilize the instrument, even a complete tube change will not make a readjustment of the frequency response of the ac amplifier necessary. However, if a consistent frequency response error is noted on all ranges above 200 kHz and accurate calibration equipment is available, the ac amplifier high frequency adjustment L2 can be used to correct this error. L2 is a small coil located between the two accuracy adjustments on the small printed circuit board on the left side of the voltmeter (see figure 13). L2 uses a coil lock which should be loosened prior to the adjustment. Lock the slug again after adjustment. Make the adjustment preferably on the 10 mV range and close to full range indication 10.00.

5.11 Attenuator Frequency Response

The attenuator high frequency response is not expected to require readjustment. However, if accurate calibration equipment is available and the amplifier response has been found flat, but large frequency errors were noted in one or more attenuator ranges, the attenuator high frequency adjustments C3, C4 and C5 can be used to correct the frequency response above 15 kHz. An insulated screwdriver should be used as an adjustment tool. (A 3/16 inch diameter insulated rod which has been slotted at one end, .04″ wide and ⅛″ deep, should serve as adjustment tool for C3 and C4 in serial #201 to #300.) The adjustment is extremely critical. All shields have to be in place, but the escutcheon plate should be removed (see 5.8). The location of the attenuator high frequency adjustments is shown in figure 12. The small strip covering the adjustment holes can be swiveled to the side. It should be returned to the original position after adjustment.

C3 affects the 100 mV range only

C4 affects the 1 V range only

C5 affects the 10 V, 100 V and 1000 V range

The attenuators change from resistive to capacitive dividers at approximately 25 kHz. Therefore the capacitive adjustment should be made at 50 kHz or higher.

5.12 Replacement of Indicating Lights

5.12.1 Overrange Indicator bulb can be replaced after removal of the cover. It is a lamp of the bayonet type. If burned out it may affect the reading speed and resolution.

To avoid this, **the light should always be kept in working condition.** It is a GE #291 or #1804 lamp.

5.12.2 Counter Illumination

The light bulb used to illuminate the counter readout is operated far below rating and should normally not require replacement. However, if for any reason the bulb should fail, remove the escutcheon plate (see 5.8) and replace the bulb, bayonet type #1820.

5.12.3 Display Lamps

The bulbs used to illuminte A, C, D, mV and the decimal points are all of the NE2H neon type and should provide a long service life. Except for the decimal points, the bulbs can be easily exchanged after removal of the escutcheon plate (see 5.8). The bulbs used for the decimal point indication are cemented in place and are more difficult to replace. In case of trouble a new counter cover assembly with mounted decimal points should be procured.

5.13 Transistor Replacement

All transistors except for Q3 and Q4 can be replaced with standard units as indicated in the parts list. Q3 and Q4 have been selected for low noise and should be procured from Ballantine Laboratories directly. However, transistor failures will be extremely infrequent. Double check the transistors prior to removal and after, to make sure that the trouble is not actually somewhere else.

5.14 Repairs on Motor-Counter Assembly

5.14.1 General

Motor-counter assembly is a mechanically moving part and, if in continued use, is subject to wear. Use of the foot switch (Model 1355) — especially the "press-to-read" mode — will increase the life of counter and multiturn potentiometer. The motor-counter assembly can be procured as a complete subassembly from Ballantine Laboratories. (State model and serial number of the instrument — see 8). If only the leaf-springs or the multiturn potentiometer are to be renewed, a complete removal of the unit is not necessary. After removing the escutcheon plate these parts are accessible. However, if the counter shows excessive wear the unit may have to be removed for repair or exchange.

5.14.2 Removal of the Motor-Counter Assembly

Remove the escutcheon plate (see 5.8).

Remove the four #2 screws which hold the counter cover and decimal points in place.

Unsolder the four leads from the 9 pin socket which lead to the motor

Pin 9	BROWN
Pin 8	BLACK
Pin 7	RED
Pin 6	YELLOW

Loosen the three binder head screws which hold the motor assembly in place (see figure 12). Note the three washers used. Unsolder three leads from the ten-turn potentiometer (colors from left to right — black, orange, white - red- violet). Remove the assembly toward the front.

To remount the assembly, proceed in reverse order.

5.14.3 Replacing the 10-Turn Potentiometer R87

Turn the gear by hand until the counter reads approximately 000. Using an Allen wrench, loosen the two set screws which hold the gear assembly to the potentiometer shaft. Loosen the nut of the potentiometer, using a ½″ across flats open end wrench.

Unsolder the three leads (see 5.14.2). The aluminum sleeve is normally supplied with the replacement potentiometer.

When replacing the potentiometer turn it fully counterclockwise. Let the terminals face away from the counter. Push the shaft through the mounting hold and slide lockwasher and nut on. Tighten nut securely. Slide on the gear assembly. Hold the potentiometer shaft fully counterclockwise and rotate the gear until the counter reads 9998 ±0.5 digits. Then tighten the set screws of the gear. Recheck the setting and free run of the assembly. The two screws which hold the mounting bracket can be used, within limits, to adjust for proper center spacing of the engaging gears.

5.15 Bail Adjustment

A front and rear bail are used on the instrument to provide both feet and a tilting device. If the instrument is to be rack mounted, these bails fold back into the instrument. If rack mounting, make sure that none of the metal of the bail touches the shields on the inside of the instrument. This would prevent a separation of signal and case ground and might produce short circuits.

Since the airflow would be restricted, do not use the instrument on the bench with bails folded back. If, in the tilted up position, the instrument collapses too easily, tighten the flat head screws which hold the mounting blocks of the bails.

TABLE IV
TROUBLESHOOTING CHART

Symptom	Possible Cause and/or Remedy	Pertinent Sections
I DC Voltmeter operates normally, but		
In ac mode noisy, all ranges	V1 noisy, microphonic Heavy line transients Unstable signal	4.4.5 2.7.4
Error in ac mode, all ranges all frequencies	AC accuracy off Tubes defective	4.4.3 5.3
Error in ac mode at low frequencies	Broken input connector Open coupling capacitor	
Error in ac mode above 10 kHz some ranges only	V1 Grid current Attenuator HF adj. off	5.5.3 5.11
Large error at 60 Hz, 120 Hz only	High hum in amplifier Cathode-filament leakage Shield missing on V1, Attenuator	4.4.5 5.3, 5.5.3
Large error at beginning of range	Defective signal diodes CR1, CR2 Noise in amplifier	 4.4.5
Excessive flutter at 30 Hz	Defective C31, C30	
Indication creeps upward	Defective C31, C30, C26 Defective tubes V1 through V4	 4.4.1
Poor common mode rejection	Internal shield missing	
II AC Amplifier and converter work normally, but in DC mode		
Large difference between +dc and −dc reading	Chopper	5.7
Creeping indication, over-range light on	High ac superimposed on dc signal Humidity on PC boards, insufficient warmup	2.12 2.7.9
III Voltmeter exhibits same problem in ac and dc modes		
No indication	Blown fuse Reading retention switch in "HOLD" position External hold	5.4 2.21 2.7.1
Error in all ranges and all voltages	DC accuracy off R80, 81, 82, 83 shifted	4.4.2
Error at beginning of range	Misadjusted zero	2.4.2
Error at specific points of each voltage range only	Ten-turn potentiometer R87 defective	5.14.3
Noisy, jittery indication	Resolution too high Q3, Q4, R87 defective Chopper noisy	4.4.2 5.13 5.7
"Friction" in the readout	Resolution too low Noisy chopper Mechanical trouble on motor-counter assembly	4.4.2 5.7 5.14
Error in some ranges only	Attenuator resistor shifted	5.9, 5.11
No steady reading, indication drifts	Chopper No reference voltage Defective transistor in servo amplifier	5.7 5.5
Indication does not change with signal	Reading retention switch in "HOLD" position Mechanical defect in motor-counter assembly Open winding on servo motor No power on servo amplifier	2.7, 2.21 5.14 5.5
Short between signal ground and case	Mounting screw clockwise Switch dials touching the escutcheon plate Motor shock mount worn	

6. SHIPPING INSTRUCTIONS

If it should be necessary to return the instrument to Ballantine Laboratories, Inc., make certain that at least four inches of padding material surrounds the instrument to prevent damage during shipment. Ship via REA Express, motor truck, or air freight, to

Ballantine Laboratories, Inc.
90 Fanny Road
Boonton, New Jersey

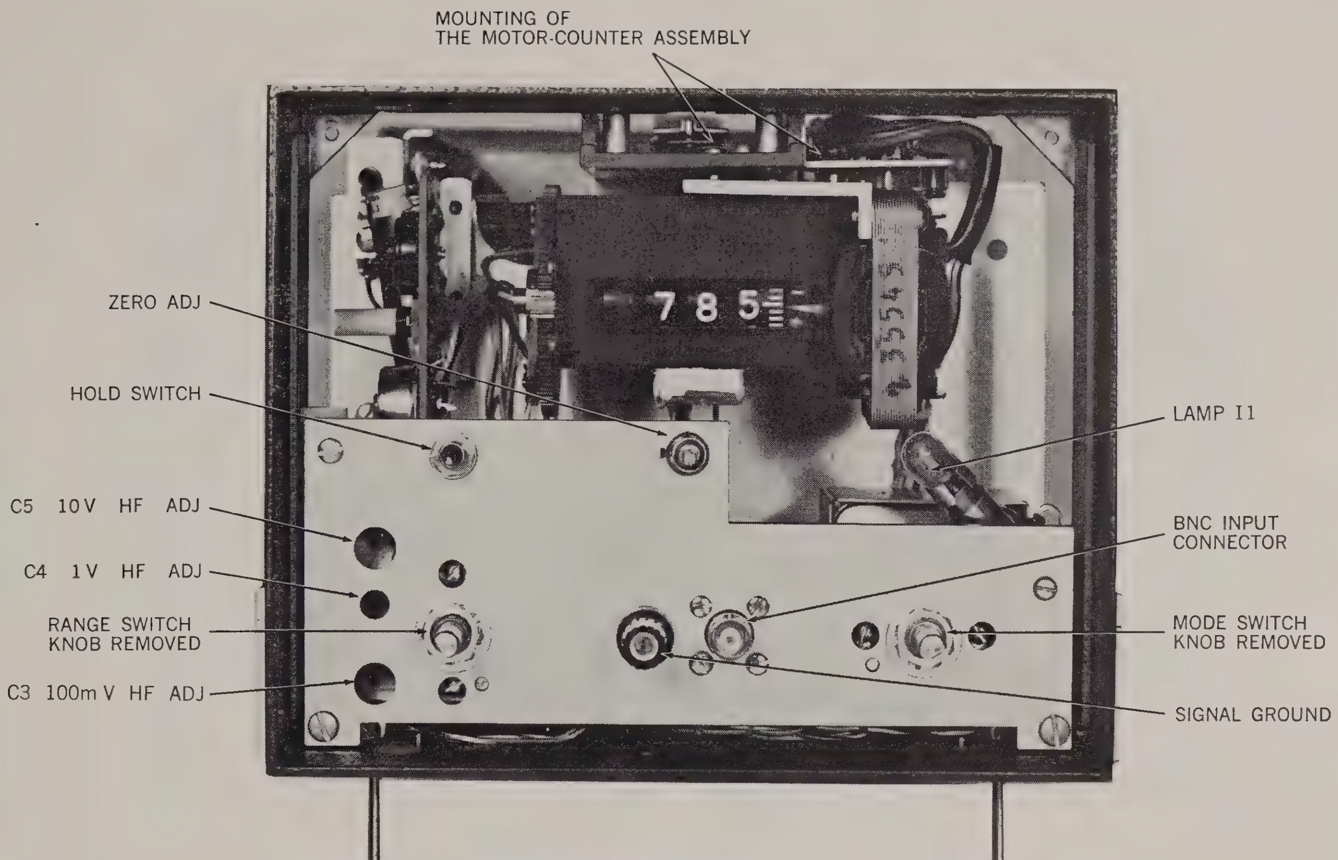


Fig. 12. Front View of Model 355

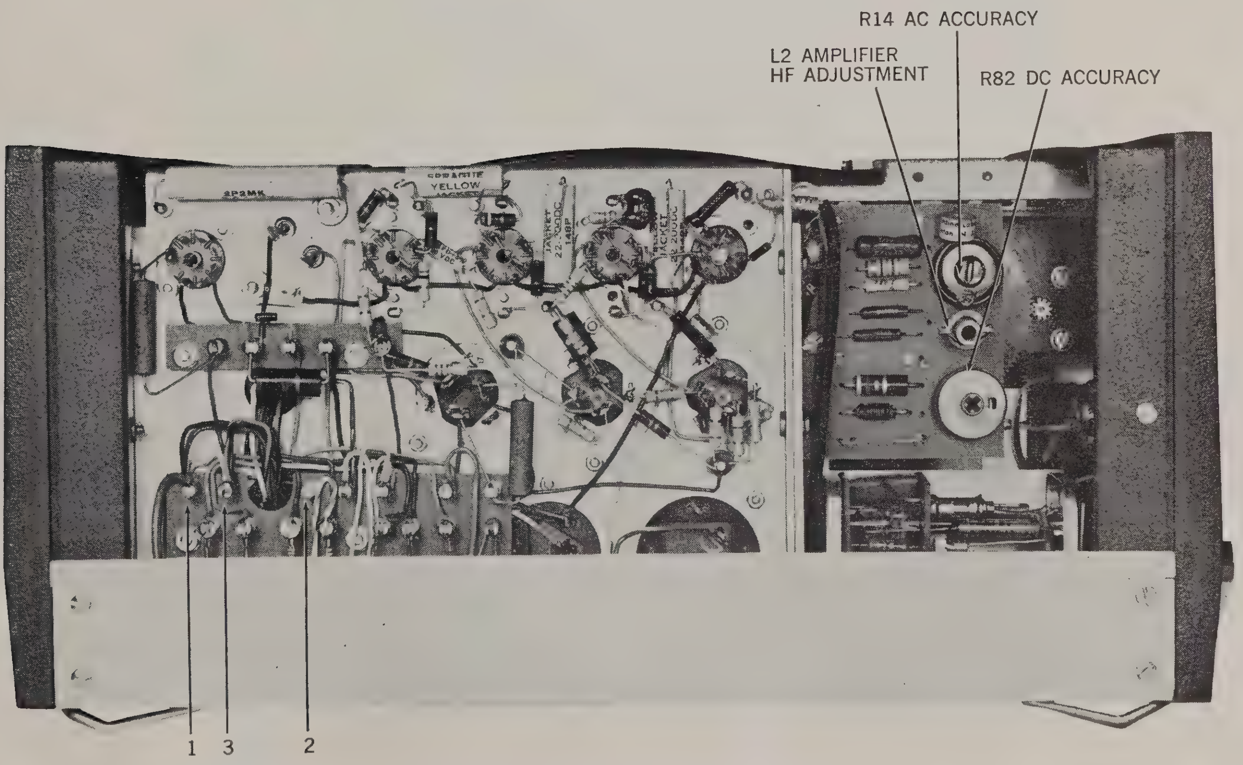


Fig. 13. Side View of Model 355

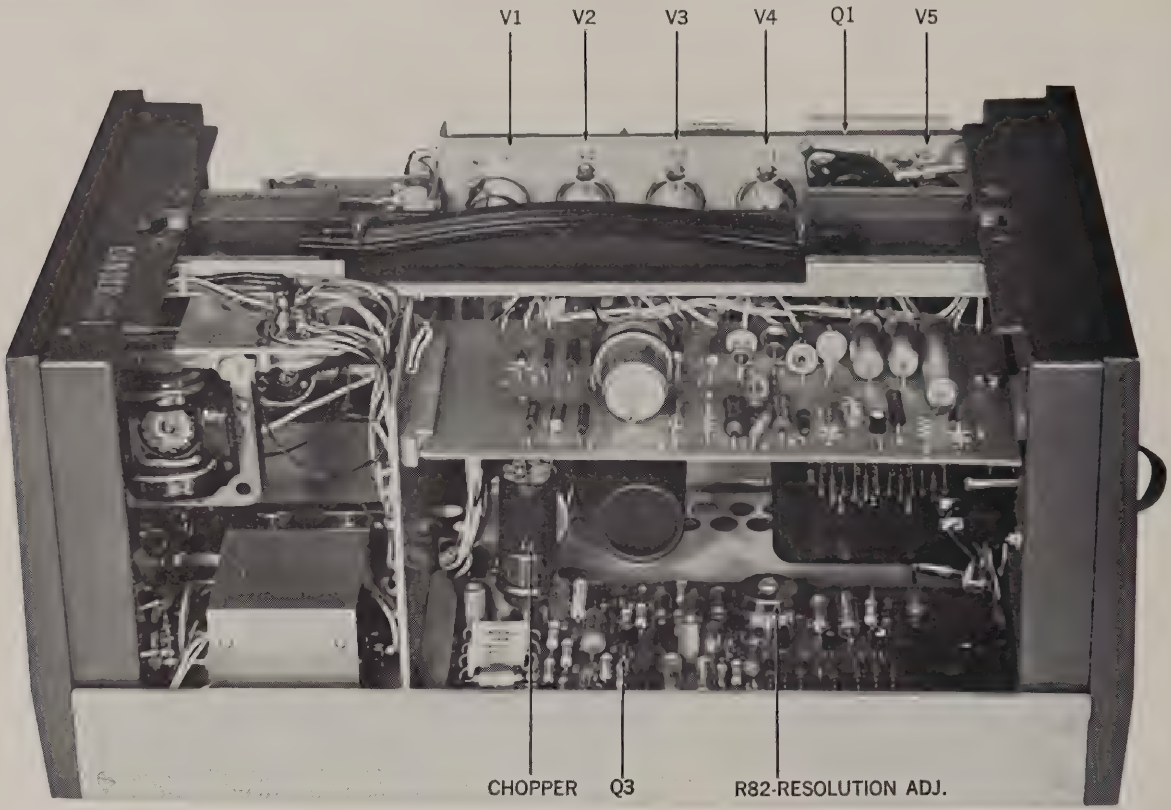


Fig. 14. Internal View of Model 355

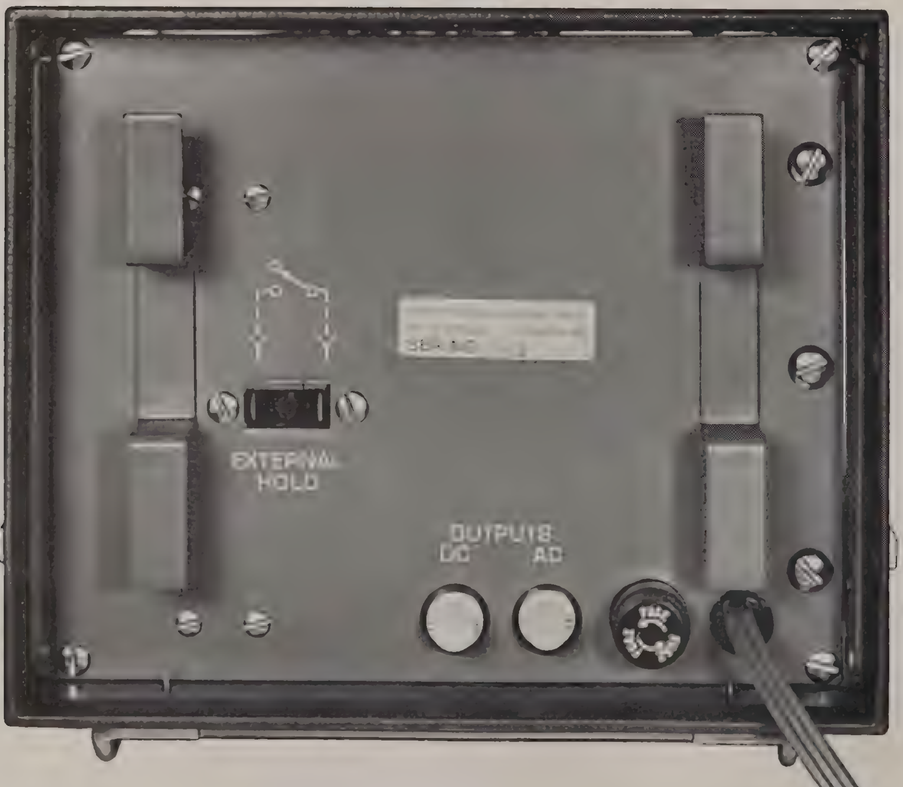


Fig. 15. Rear view of Model 355

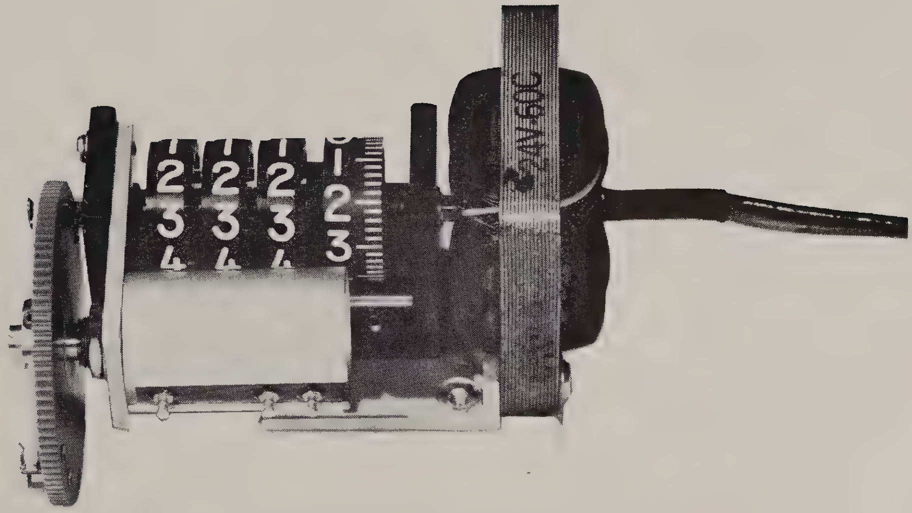
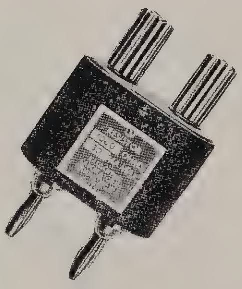
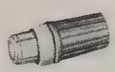


Fig. 16. Motor-Counter Assembly

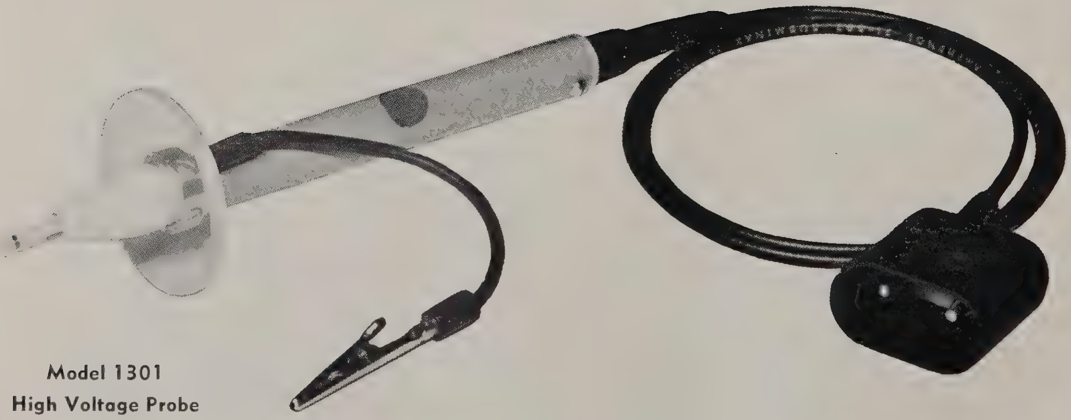
Model 1355
Foot Switch





Model 618
BNC-to-Binding Post Adapter
(1 Supplied with the Model 355)

Series 600
Precision Shunt Resistor



Model 1301
High Voltage Probe

Fig. 17. Accessories for Model 355

7. REPLACEMENT PARTS LIST

REFER TO MODEL 355 CIRCUIT DIAGRAM, DWG. ME-3090E

B. L. Part No.	Circuit Symbol	Capacitors	Manufacturer
8112	C1	0.068 μF, 10%, 600 V, Type 364F683K	Gudeman
2457	C3	0.8-8.5 pF, 1300 V, Type V1228	Voltronics
2457	C4	0.8-8.5 pF, 1300 V, Type V1228	Voltronics
2457	C5	0.8-8.5 pF, 1300 V, Type V1228	Voltronics
2235	C6	33 pF, 5%, Type CM15-E-330J	Arco
2254	C7	330 pF, 5%, 500 V, Type CM15-E-331J	Arco
2255	C8	3300 pF, 5%, 500 V, Type CM20-E-332J	Arco
2563	C9	22 pF, ±10%, 500 V, Type QC	Quality Components
2397	C15	50 pF, 5%, 125 V, Type Styro Kap	Centralab
2797	C16	1000 μF, 5 V, Type 601D128G005GE4	Sprague
2042	C17A	50 μF, 150 V, Type DFP	Sprague
	C17B	50 μF, 150 V, Type DFP	Sprague
	C17C	50 μF, 150 V, Type DFP	Sprague
2362	C18	.22 μF, 5%, 200 V, Type 355C224J	Gudeman
2240	C19	20 pF, 5%, 500 V, Type CM15-C-200J	Arco
2273	C20	250 pF, 5%, 500 V, Type DM-15-251-J	Arco
2042	C21A	50 μF, 150 V, Type DFP	Sprague
	C21B	50 μF, 150 V, Type DFP	Sprague
	C21C	50 μF, 150 V, Type DFP	Sprague
2362	C22	.22 μF, 5%, 200 V, Type 355C224J	Gudeman
2273	*C23	250 pF, 5%, 500 V, Type DM-15-251-J	Arco
2362	C24	.22 μF, 5%, 200 V, Type 355C224J	Gudeman
2365	C25	.01 μF, 5%, 200 V, Type 355C103J	Gudeman
8111	C26	2 μF, 10%, 200 V, Type 2P2MK	Hopkins
2043	C27A	10 μF, 500 V, Type DFP	Sprague
	C27B	10 μF, 500 V, Type DFP	Sprague
	C27C	10 μF, 500 V, Type DFP	Sprague
2572	C30	4.7 μF, ±20%, 6VDC, Type 150D 475 X 0006 A2	Sprague
2068	C31	50 μF, 6 V, Type TNT 506 U 006 POB	Mallory
2068	C32	50 μF, 6 V, Type TNT 506 U 006 POB	Mallory
2541	C33	.01 μF, GMV Tol., 500 V, Type 19C241 Disc	Sprague
2796	C34	1500 pF, 10%, 200 V, Type 192P15292	Sprague
7814	C35	1 μF, 12 V, Type 30D105 G 102 AA4	Sprague
2799	C40	250 μF, 50 V, Type DFP	Sprague
7812	C41	50 μF, 50 V, Type 30D506 G 050 DH4	Sprague
2754	C42A	1000 μF, 25 V, Type DFP	Sprague
	C42B	1000 μF, 25 V, Type DFP	Sprague
2796	C43	1500 pF, 10%, 200 V, Type 192P15292	Sprague
7815	C44	15 μF, 20 V, Type 150D156X0020B2	Sprague
7815	C45	15 μF, 20 V, Type 150D156X0020B2	Sprague
2371	C50	.047 μF, 10%, 200 V, Type 148P47392	Sprague
2796	C51	1500 pF, 10%, 200 V, Type 192P15292	Sprague
2371	C52	.047 μF, 10%, 200 V, Type 148P47392	Sprague
2795	C53	2700 pF, 10%, 200 V, Type 192P27292	Sprague
2371	C54	.047 μF, 10%, 200 V, Type 148P47392	Sprague
2371	C55	.047 μF, 10%, 200 V, Type 148P47392	Sprague

*In some instruments the component listed may not be used at all or its value may differ from the value shown.

REPLACEMENT PARTS LIST (Continued)

REFER TO MODEL 355 CIRCUIT DIAGRAM, DWG. ME-3090E

B. L. Part No.	Circuit Symbol	Capacitors	Manufacturer
2541	C59	.01 µF, GMV Tol., 500 V, Type 19C241 Disc	Sprague
2358	C60	.022 µF, 10%, 200 V, Type 148P22392	Sprague
2394	C61	.1 µF, 5%, 200 V, Type 192P10452	Sprague
7814	C62	1 µF, 12 V, Type 30D105 G 012 AA4	Sprague
2086	C63	25 µF, 12 V, Type 30D256 G 012 BB4	Sprague
2796	C64	1500 pF, 10%, 200 V, Type 192P15292	Sprague
7814	C65	1 µF, 12 V, Type 30D105 G 012 AA4	Sprague
2086	C66	25 µF, 12 V, Type 30D256 G 012 BB4	Sprague
7814	C67	1 µF, 12 V, Type 30D105 G 012 AA4	Sprague
2086	C68	25 µF, 12 V, Type 30D256 G 012 BB4	Sprague
7814	C69	1 µF, 12 V, Type 30D105 G 012 AA4	Sprague
2086	C70	25 µF, 12 V, Type 30D256 G 012 BB4	Sprague
2088	C71	50 µF, 25 V, Type 30D506 G 025 DD4	Sprague
2088	C72	50 µF, 25 V, Type 30D506 G 025 DD4	Sprague
		Resistors	
1476	R1 (1)	1,800,000 ohms, 1%, Type PT-1000	Pyrofilm
1477	R2 (2)	2,000,000 ohms, 1%, Type PT-500	Pyrofilm
1478	R3 (3)	1,998,000 ohms, 1%, Type PT-1000	Pyrofilm
1007	R4	2,000,000 ohms, 5%, Type EB	Allen-Bradley
1441	R5 (1)	200,000 ohms, 1%, Type PT-500	Pyrofilm
1442	R6 (2)	20,200 ohms, 1%, Type PT-500	Pyrofilm
1443	R7 (3)	1,800 ohms, 1%, Type PT-500	Pyrofilm
1444	R8 (3)	180 ohms, 1%, Type PT-500	Pyrofilm
1445	R9 (3)	20 ohms, 1%, Type PT-500	Pyrofilm
6858	R14	10,000 ohms, ±20%, Type TSRB 1032	Allen-Bradley
1348	R15	250 ohms, 1%, Type CPX-½	Aerovox
1120	R16	2,200 ohms, 10%, Type CB	Allen-Bradley
1697	R17	1,200 ohms, 1%, Type N20	Corning
1433	*R18	764 ohms, 1%, Type CPX-½	Aerovox
6068	R19	39,000 ohms, 5%, Type E009AB/B 39K	Amperex
1660	R20	47,000 ohms, 1%, Type N-20	Corning
1329	R21	4,700 ohms, 2%, Type CPX-½	Aerovox
7267	R22	7,870 ohms, 1%, Type MF-6C-D-7871-F	Electra
1769	R23	7.35 ohms, 1%, Special	Ballantine
6057	R24	27,000 ohms, 5%, Type E009AB/B 27K	Amperex
6068	R25	39,000 ohms, 5%, Type E009AB/B 39K	Amperex
1009	R26	1,500,000 ohms, 5%, Type EB	Allen-Bradley
6061	R27	510 ohms, 5%, Type E009AB/B 510E	Amperex
1039	R28	22,000 ohms, 5%, Type EB	Allen-Bradley
2647	R29	12,000 ohms, 5%, Type E009AB/B 12K	Amperex
6060	R30	7,500 ohms, 5%, Type E009AB/B 7K5	Amperex
6058	R31	18,000 ohms, 5%, Type E009AB/B 18K	Amperex

(1) Resistors R1, R5 are part of a matched set and must be purchased as Set No. 1597.

(2) Resistors R2, R6 are part of a matched set and must be purchased as Set No. 1598.

(3) Resistors R3, R7, R8, R9 are part of a matched set and must be purchased as Set No. 1596.

* In some instruments the component listed may not be used at all or its value may differ from the value shown.

REPLACEMENT PARTS LIST (Continued)

REFER TO MODEL 355 CIRCUIT DIAGRAM, DWG. ME-3090E

B. L. Part No.	Circuit Symbol	Resistors	Manufacturer
6057	R32	27,000 ohms, 5%, Type E009AB/B 27K	Amperex
1010	R33	1,000,000 ohms, 5%, Type EB	Allen-Bradley
1062	R34	390 ohms, 5%, Type EB	Allen-Bradley
6060	R35	7,500 ohms, 5%, Type E009AB/B 7K5	Amperex
6058	R36	18,000 ohms, 5%, Type E009AB/B 18K	Amperex
6057	R37	27,000 ohms, 5%, Type E009AB/B 27K	Amperex
1007	*R38	2,000,000 ohms, 5%, Type EB	Allen-Bradley
1007	R39	2,000,000 ohms, 5%, Type EB	Allen-Bradley
6055	R40	100,000 ohms, 5%, Type E009AB/B 100K	Amperex
1063	R41	300 ohms, 5%, Type EB	Allen-Bradley
6058	R42	18,000 ohms, 5%, Type E009AB/B 18K	Amperex
1042	R43	15,000 ohms, 5%, Type EB	Allen-Bradley
6192	R50	11,380 ohms, 0.25%, Type EP43E1C-11.38K	Shallcross
6190	R51	100,000 ohms, 0.25%, Type EP43E1C-100K	Shallcross
6185	R52	1,667 ohms, 0.25%, Type EP43E1C-1.667K	Shallcross
1655	R53	694 ohms, 1%, Type N-20	Corning
6185	R54	1,667 ohms, 0.25%, Type EP43E1C-1.667K	Shallcross
1018	*R55	360,000 ohms, 5%, Type EB	Allen-Bradley
1678	R56	4,700 ohms, 5%, Type C-20	Corning
1331	R57	3,000 ohms, 1%, Type CPX-½	Aerovox
1731	R60	3,200 ohms, 5%, Type 452E	Sprague
1039	R61	22,000 ohms, 5%, Type EB	Allen-Bradley
1138	*R62	1.8 ohms, 10%, Type EB	Allen-Bradley
1739	R63	22 ohms, 5%, Type 151E	Sprague
1731	R64	3,200 ohms, 5%, Type 452E	Sprague
1024	*R65	150,000 ohms, 5%, Type EB	Allen-Bradley
6191	R66	760 ohms, ±1%, Type E20	R.C.L.
1208	R67	2,000 ohms, 5%, Type HB	Allen-Bradley
2649	R70	120,000 ohms, 5%, Type E009AB/B 120K	Amperex
2649	R71	120,000 ohms, 5%, Type E009AB/B 120K	Amperex
1281	R72	180,000 ohms, 5%, Type GB	Allen-Bradley
2649	R73	120,000 ohms, 5%, Type E009AB/B 120K	Amperex
2649	R74	120,000 ohms, 5%, Type E009AB/B 120K	Amperex
7207	*R80	3,300 ohms, 1%, Type N-20	Corning
6186	R81	40,800 ohms, 0.25%, Type EP43E1C-40.8K	Shallcross
6851	R82	1,000 ohms, 10%, Type 115	CTS
6188	R83	538 ohms, 0.25%, Type EP43E1C-538 ohms	Shallcross
1278	R84	4.7 ohms, 5%, Type GB	Allen-Bradley
1039	*R85	22,000 ohms, 5%, Type EB	Allen-Bradley
1784	R86	0.45 ohms, 10%, Special	Ballantine
6855	R87	10,000 ohms, ±3%, Type 7216R10KL.1	Beckman-Helipot
6857	R88	100 ohms, 20%, Type G	Allen-Bradley
2648	R90	470,000 ohms, 5%, Type E009AB/B 470K	Amperex
2648	R91	470,000 ohms, 5%, Type E009AB/B 470K	Amperex
6055	R92	100,000 ohms, 5%, Type E009AB/B 100K	Amperex
6055	R93	100,000 ohms, 5%, Type E009AB/B 100K	Amperex
6056	R94	51,000 ohms, 5%, Type E009AB/B 51K	Amperex

* In some instruments the component listed may not be used at all or its value may differ from the value shown.

REPLACEMENT PARTS LIST (Continued)

REFER TO MODEL 355 CIRCUIT DIAGRAM, DWG. ME-3090E

B. L. Part No.	Circuit Symbol	Resistors	Manufacturer
6059	R95	10,000 ohms, 5%, Type E009AB/B 10K	Amperex
1054	R96	2,000 ohms, 5%, Type EB	Allen-Bradley
1120	R97	4,700,000 ohms, 5%, Type EB	Allen-Bradley
6057	R98	27,000 ohms, 5%, Type E009AB/B 27K	Amperex
6057	R99	27,000 ohms, 5%, Type E009AB/B 27K	Amperex
1110	R100	2,400,000 ohms, 5%, Type EB	Allen-Bradley
1039	R101	22,000 ohms, 5%, Type EB	Allen-Bradley
6859	R102	4,000 ohms, ±20%, Type 115	CTS
1018	R103	360,000 ohms, 5%, Type EB	Allen-Bradley
1089	R104	3,300 ohms, 5%, Type EB	Allen-Bradley
1039	R105	22,000 ohms, 5%, Type EB	Allen-Bradley
6059	R106	10,000 ohms, 5%, Type E009AB/B 10K	Amperex
1063	R107	300 ohms, 5%, Type EB	Allen-Bradley
1067	R108	150 ohms, 5%, Type EB	Allen-Bradley
1062	R109	390 ohms, 5%, Type EB	Allen-Bradley
1739	R110	22 ohms, 5%, Type 151E	Sprague
1024	R120	150,000 ohms, 5%, Type EB	Allen-Bradley
1024	R121	150,000 ohms, 5%, Type EB	Allen-Bradley
1024	R122	150,000 ohms, 5%, Type EB	Allen-Bradley
1024	R123	150,000 ohms, 5%, Type EB	Allen-Bradley
1024	R124	150,000 ohms, 5%, Type EB	Allen-Bradley

Other Components

7920	CR1	Diode, Type 1N4148	General Electric
7920	CR2	Diode, Type 1N4148	General Electric
5594	CR3	Diode, Type BY-100	Amperex
5594	CR4	Diode, Type BY-100	Amperex
7918	CR5	Rectifier, Type 1N1218, PIV, 100 V	Westinghouse
7918	CR6	Rectifier, Type 1N1218, PIV, 100 V	Westinghouse
7918	CR7	Rectifier, Type 1N1218, PIV, 100 V	Westinghouse
7918	CR8	Rectifier, Type 1N1218, PIV, 100 V	Westinghouse
7918	CR9	Rectifier, Type 1N1218, PIV, 100 V	Westinghouse
7918	CR10	Rectifier, Type 1N1218, PIV, 100 V	Westinghouse
7918	CR11	Rectifier, Type 1N1218, PIV, 100 V	Westinghouse
7918	CR12	Rectifier, Type 1N1218, PIV, 100 V	Westinghouse
7910	CR13	Diode, Zener, Type 1N957B, ±5%, 6.8 V	Hughes
7910	CR14	Diode, Zener, Type 1N957B, ±5%, 6.8 V	Hughes
7911	CR15	Diode, Zener, 1N936, 8.55 V to 9.45 V	Motorola
7920	CR16	Diode, Type 1N4148	General Electric
7920	CR17	Diode, Type 1N4148	General Electric
7910	CR18	Diode, Zener, Type 1N957B, ±5%, 6.8 V	Hughes
7912	CR19	Diode, Zener, 1N961B, ±5%, 10 V	Hughes
2802	F1	Fuse, 0.60 A, Type 3AG-0.6, Slo-Blo	Littelfuse
3486	I1	Overrange Light, Type 291 (Supersedes Type 1809)	General Electric
3485	I2	Counter Light, Type #1820	General Electric
3068	L1	Coil, Special	Ballantine
6257	L2	Coil, Special	Ballantine

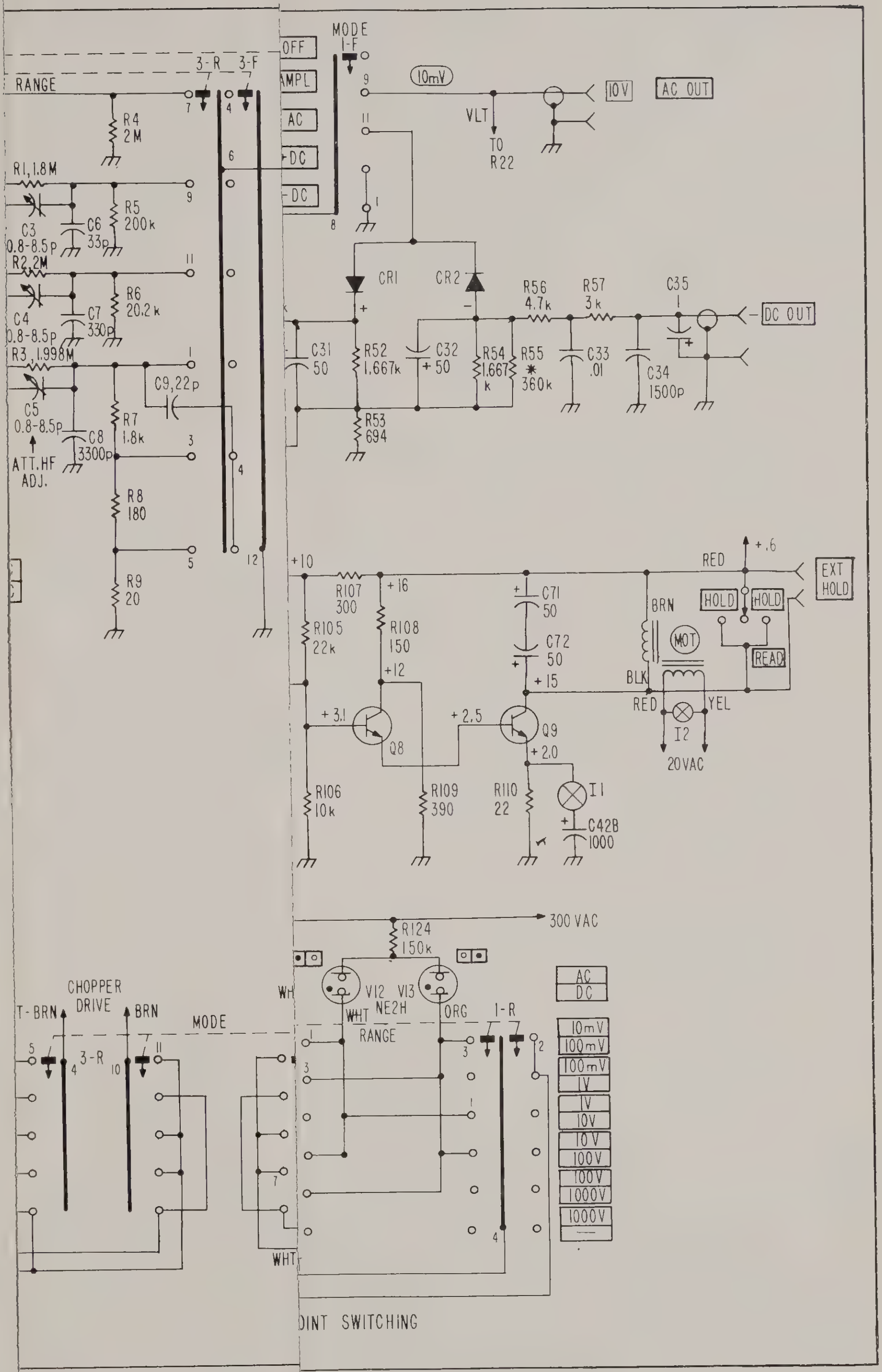
REPLACEMENT PARTS LIST (Continued)

REFER TO MODEL 355 CIRCUIT DIAGRAM, DWG. ME-3090E

B. L. Part No.	Circuit Symbol	Other Components	Manufacturer
7914	Q1	Transistor, Germanium Power, Type MP1535	Motorola
7915	Q2	Transistor, Type 2N2924	General Electric
7915	Q3	Transistor, Type 2N2924	General Electric
7915	Q4	Transistor, Type 2N2924	General Electric
7915	Q5	Transistor, Type 2N2924	General Electric
7915	Q6	Transistor, Type 2N2924	General Electric
7915	Q7	Transistor, Type 2N2924	General Electric
7915	Q8	Transistor, Type 2N2924	General Electric
7916	Q9	Transistor, Silicon Power, Type 2N3054	RCA
7756	S1	Switch, Attenuator, Special	Ballantine
7757	S2	Switch, Function, Special	Ballantine
7758	S3	Switch, Toggle, Type MST-105H	Alco
6255	T1	Transformer, Power, Special	Ballantine
7907	V1	Tube, Type 6AU6A, Code 16, RCA only	RCA
7907	V2	Tube, Type 6AU6A, Code 16, RCA only	RCA
7907	V3	Tube, Type 6AU6A, Code 16, RCA only	RCA
7907	V4	Tube, Type 6AU6A, Code 16, RCA only	RCA
3106	V5	Tube, Type OA2	RCA
7917	V6	Tube, Type NE2H C2A	General Electric
7917	V7	Tube, Type NE2H C2A	General Electric
7917	V8	Tube, Type NE2H C2A	General Electric
7917	V9	Tube, Type NE2H C2A	General Electric
7917	V10	Tube, Type NE2H C2A	General Electric
7917	V11	Tube, Type NE2H C2A	General Electric
7917	V12	Tube, Type NE2H C2A	General Electric
7917	V13	Tube, Type NE2H C2A	General Electric
4156	—	AC Power Cord	Ballantine
3084	G1	Chopper, Type M3	Airpax

8. MECHANICAL PARTS WHICH MAY REQUIRE REPLACEMENT

B. L. Part No.	Description	Consists of	
8306	Counter Motor Assembly (Ser. #101-200)	1 10 Turn Potentiometer	2 Roll Pin
		1 Motor	1 Bushing
		1 Counter	4 Spring
		1 Gear	1 Shoulder Nut
		1 Pinion	1 Sleeve
		4 Stud (Spring Stop)	1 Bracket
			2 Post
8313	Counter Motor Assembly (Ser. #201 - up)	1 10 Turn Potentiometer	2 Roll Pin
		1 Motor	1 Bushing
		1 Counter	4 Spring
		1 Gear	1 Sleeve
		4 Stud (Spring Stop)	3 Stand-off Post
		1 Bracket (Potentiometer)	1 Bracket (Counter Mounting)
8307	Counter Cover and Decimal Point Assembly (Ser. #101-200)	2 Reflector	
		2 Lamp	
		1 Cover	
8314	Counter Cover and Decimal Point Assembly (Ser. #201 - up)	2 Reflector	
		2 Lamp	
		1 Cover	
8308	Gear Assembly	4 Stud (Spring Stop)	
		1 Gear	
		2 Roll Pin	
8315	Handle Assembly	1 Handle	
		2 Stud	
		2 Roll Pin	
8309	Mode Switch Dial Asembly (Ser. #101-300)	1 Dial	
		1 Marking	
		1 Hub	
8206	Mode Switch Dial and Knob (Ser .#301 - up)		
8310	Range Switch Dial Assembly (Ser. #101-300)	1 Dial	
		1 Marking	
		1 Hub	
8207	Range Switch Dial and Knob		
8312	10 Turn Potentiometer Assembly (Ser. #101-200)	1 10 Turn Helipot	
		1 Sleeve	
		1 Shoulder Nut	
8316	10 Turn Potentiometer Assembly (Ser. #201 - up)	1 10 Turn Helipot	
		1 Sleeve	



tic of Model 355 AC-DC Digital Voltmeter

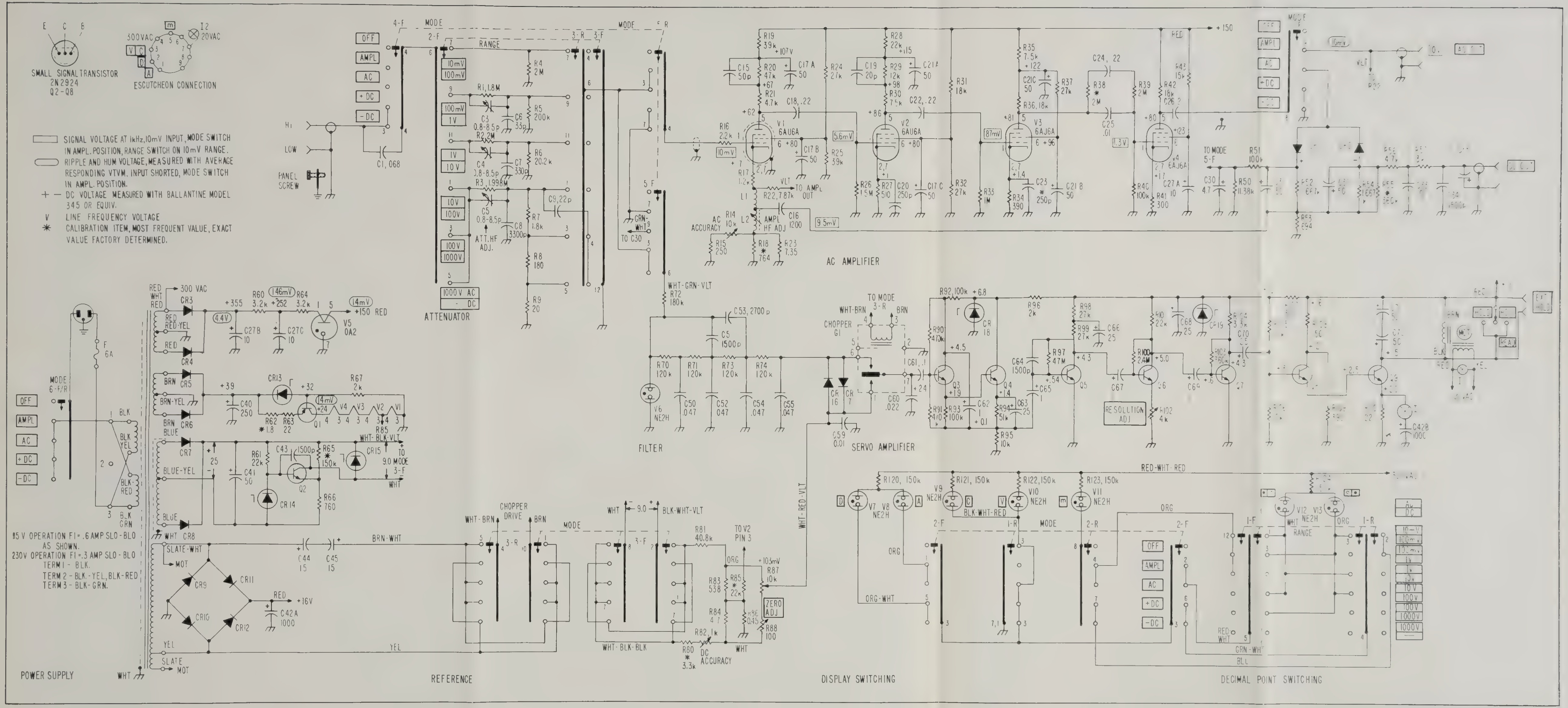
rawing No. ME-3090E

NTINE LABORATORIES, INC.

Boonton, New Jersey

8. MECHANICAL PARTS WHICH MAY REQUIRE REPLACEMENT

B. L. Part No.	Description	Consists of	
8306	Counter Motor Assembly (Ser. #101-200)	1 10 Turn Potentiometer 1 Motor 1 Counter 1 Gear 1 Pinion 4 Stud (Spring Stop)	2 Roll Pin 1 Bushing 4 Spring 1 Shoulder Nut 1 Sleeve 1 Bracket 2 Post
8313	Counter Motor Assembly (Ser. #201 - up)	1 10 Turn Potentiometer 1 Motor 1 Counter 1 Gear 4 Stud (Spring Stop) 1 Bracket (Potentiometer)	2 Roll Pin 1 Bushing 4 Spring 1 Sleeve 3 Stand-off Post 1 Bracket (Counter Mounting)
8307	Counter Cover and Decimal Point Assembly (Ser. #101-200)	2 Reflector 2 Lamp 1 Cover	
8314	Counter Cover and Decimal Point Assembly (Ser. #201 - up)	2 Reflector 2 Lamp 1 Cover	
8308	Gear Assembly	4 Stud (Spring Stop) 1 Gear 2 Roll Pin	
8315	Handle Assembly	1 Handle 2 Stud 2 Roll Pin	
8309	Mode Switch Dial Asembly (Ser. #101-300)	1 Dial 1 Marking 1 Hub	
8206	Mode Switch Dial and Knob (Ser .#301 - up)		
8310	Range Switch Dial Assembly (Ser. #101-300)	1 Dial 1 Marking 1 Hub	
8207	Range Switch Dial and Knob		
8312	10 Turn Potentiometer Assembly (Ser. #101-200)	1 10 Turn Helipot 1 Sleeve 1 Shoulder Nut	
8316	10 Turn Potentiometer Assembly (Ser. #201 - up)	1 10 Turn Helipot 1 Sleeve	


E C B
SMALL SIGNAL TRANSISTOR
2N2924
Q2-Q8
300VAC
I2
20VAC
ESCUTCHEON CONNECTION
SIGNAL VOLTAGE AT 1kHz, 10mV INPUT, MODE SWITCH IN AMPL. POSITION, RANGE SWITCH ON 10mV RANGE.
RIPPLE AND HUM VOLTAGE, MEASURED WITH AVERAGE RESPONDING VTVM. INPUT SHORTED, MODE SWITCH IN AMPL. POSITION.
+ — DC VOLTAGE MEASURED WITH BALLANTINE MODEL 345 OR EQUIV.
V LINE FREQUENCY VOLTAGE
✳ CALIBRATION ITEM, MOST FREQUENT VALUE, EXACT VALUE FACTORY DETERMINED.
HI
LOW
PANEL SCREW
MODE
RANGE
OFF
AMPL
AC
+DC
-DC
ATTENUATOR
AC AMPLIFIER
FILTER
SERVO AMPLIFIER
CHOPPER G1
RESOLUTION ADJ
POWER SUPPLY
REFERENCE
CHOPPER DRIVE
DISPLAY SWITCHING
ZERO ADJ
DC ACCURACY
DECIMAL POINT SWITCHING
115 V OPERATION F1=.6 AMP SLO-BLO AS SHOWN.
230V OPERATION F1=.3 AMP SLO-BLO
TERM 1 - BLK.
TERM 2 - BLK-YEL, BLK-RED
TERM 3 - BLK-GRN.

CAPACITORS: NOT MARKED — MICROFARDS (10^{-6} F)
P — PICOFARADS (10^{-12} F)
PESISTORS- NOT MARKED — OHMS (Ω)
k — KILOHMS (10^{3}Ω)
M — MEGOHMS (10^{6}Ω)
VOLTAGE NOT MARKED — VOLTS (V)
mV — MILLVOLTS (10^{-3}V)

Figure 18. Schematic of Model 355 AC-DC Digital Voltmeter
Drawing No. ME-3090E

BALLANTINE LABORATORIES, INC.
Boonton, New Jersey

BALLANTINE LABORATORIES, INC.
Precision Electronic Measuring Equipment
BOONTON, NEW JERSEY 07005

TEL. 201 - 334-1432
TWX 510 - 235-8329

17 August 1966

Commanding Officer
Picatinny Arsenal
Dover, New Jersey

Att: SMUPA-N1-2, Bldg. 3325

Subject: Your Order No. 28-017-A6-10336(A) Date Shipped: 4-1-66

Gentlemen:

On the referenced purchase order you bought a Ballantine Model 355 AC/DC Digital Voltmeter, Serial No. 254.

Recently we learned that a few of our customers have encountered an operational problem with instruments having serial numbers below 301.

This problem (slow running, or noisy counters) is readily corrected by lubricating according to the enclosed instructions.

We'd greatly appreciate your forwarding this information, along with the oiler, to the person using the instrument, or to your repair facility so that appropriate action can be taken.

If you should need any assistance, we hope that you will get in touch with us, or with our representative in your area, as we want to make sure that the instrument you purchased is in top working order.

Very truly yours,

BALLANTINE LABORATORIES, INC.

Robert C. Dorris
Vice President, Marketing

rcd/mm/enc

BALLANTINE LABORATORIES, INC.
BOONTON, N. J.

SPECIFICATION No. MS-299
Sheet 1 of 1 Sheets

ISSUED BY A. Cannara
APPROVED BY
DATE: 18 July '66

TITLE:
LUBRICATION INSTRUCTIONS
FOR MODEL 355

Ballantine Model 355 Digital Voltmeters with Serial Numbers below 301 may require lubrication with Univis P48 Silicone Oil in order to correct a slow-running, or noisy counter. Instruments with higher Serial Numbers have already been lubricated and may never need such service. A convenient oiling device is supplied for each instrument.

To oil any 355 with a Serial Number below 201, remove the knobs, cover, escutcheon plate (outer front panel) and counter mask. Place no more than two drops of oil on each outer counter bearing and the outer motor bearing. Reassemble the instrument, being careful to align the mask so that it does not touch the counter wheels.

For instruments with Serial Numbers above 200, remove the cover and bottom plate only. Apply no more than two drops of oil to the two bearings in the counter frame.

If the oiler is misplaced, a new one may be obtained from Ballantine Laboratories, at no charge, by requesting Part Number 8707.

CHANGE	DATE

LCWSL NAD B 64 6252745985
LAQUELLETTE L0022 GMT

CALIBRATION PROCEDURE SUMMARY SHEET

AC-DC DIGITAL VOLTMETER

012750

MANUFACTURER: BALLANTINE LABS

4. MANUFACTURER MODEL NO: 355

5. ORIG. PROCEDURE NO: 33K6-4-1(471)

6. ORIGINATORS PROCEDURE TITLE:

7. DATE OF	DAY	MO	YR
ISSUE	1	11	68
REVISION			

8. TYPE OF PROCEDURE

☐ GENERAL PROCEDURE ☑ SPECIFIC PROCEDURE

9. IS THIS PROCEDURE WRITTEN IN THE NCSL RECOMMENDED FORMAT OR MIL-M-38793? YES ☑ NO ☐

10. THIS PROCEDURE (SUPERSEDES) ☐ (REVISES) ☐ ACCESS NO.:

11. ADDITIONAL COMMENTS:

012750

12. COPY OF PROCEDURE SENT TO MANUFACTURER ☑

13. SIGNED: W.E. Kloetz

14. COMPANY NAME, CITY & STATE: AGMC NEWARK AFS OHIO

15. PARTICIPANT CODE: FW

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NOTICES PAGE

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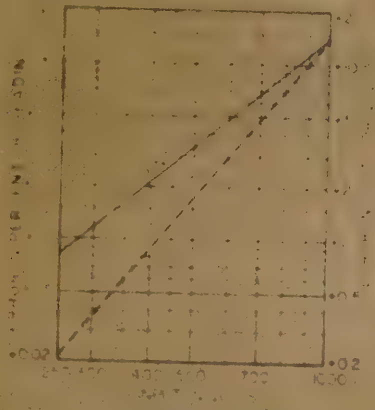
Test Instrument Characteristics	Performance Specifications	Test Method
DC Voltage	Range: 0 to 1000V (6 ranges) Accuracy: 1MV to 500V ±0.25% of FS, 500 to 1000V ±0.25% of FS. Additional uncertainty after subtracting correction from chart below.  Error of Indication as Function of the Input Voltage	Compared against DC V Standard
AC Voltage	Range: 0 to 1000V (6 ranges) Accuracy: 1MV to 500V 50 Hz to 10KHz ±0.25% of FS. 30 Hz to 50KHz ± 0.5% of FS. 50KHz to 250KHz ± 1% of FS. 500V to 1000V additional ±0.25% of FS. Uncertainty same as DC Voltage.	Compared to a Standard Voltage across frequency range.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2.1	INSTRUMENT CALIBRATION STANDARD	Range: 0 to 900V Accuracy: ±0.05	Weston 61	
2.2	AC VOLTAGE STANDARD	Range: 0 to 900V Accuracy: ±(0.05% + 1MV) @ 50 Hz, 400 Hz, 10KHz	Rotek 150	
2.3	AC VOLTAGE DIVIDER	Range: 0 to .0900000 @ 50 Hz to 10 KHz Terminal Linearities ±0.5PPM @ 50 and 400 Hz, ±50 PPM @ 10KHz	Electro Scientific Ind., DT-72A	
2.4	FREQUENCY RESPONSE TEST SET	Range: 0.009 to 3 Volts Frequency Response ±0.5% @ 30 Hz to 250 KHz	Hewlett-Packard, 739A	
2.5	OSCILLATOR	Range: 30 Hz, 400 Hz, 50 KHz, 250 KHz Accuracy: N/A	Hewlett-Packard, 200S	

3.0 PRELIMINARY OPERATIONS

3.1 Read entire procedure before beginning calibration.

3.2 Connect Test Instrument to 115V, 60Hz, and set the MODE switch to AMPL. Allow for a 15 minute warm-up period.

3.3 Set Test Instrument HOLD-READ-HOLD switch to READ, adjust the ZERO ADJ. control until the Test Instrument readout indicates 000 ± 0.3 digits.

3.4 When measuring voltages above 300 Volts, the Test Instrument indication will drift due to heating of the input attenuator. The correct voltage will be observed only after the indicator stabilizes.

4.0 CALIBRATION PROCESS:

NOTE

UNLESS OTHERWISE SPECIFIED, VERIFY THE RESULTS OF EACH TEST AND TAKE CORRECTIVE ACTION BEFORE PROCEEDING.

4.1 DC VOLTAGE CALIBRATION:

4.1.1 Set up Instrument Calibration Standard to produce +DC Volts.

4.1.2 Set Test Instrument MODE switch to +DC.

4.1.3 Connect Test Instrument Input jack to Instrument Calibration Standard MILLIVOLTS terminals observing polarity.

[illegible]	[illegible]	Test Instrument Limits
100 MV	90.0 MV	89.75 to 90.25 MV
*1 V	0.9 V	0.8975 to 0.9025 V
*10 V	9.0 V	8.975 to 9.025 V
	8.0 V	7.975 to 8.025 V
	7.0 V	6.975 to 7.025 V
	6.0 V	5.975 to 6.025 V
	5.0 V	4.975 to 5.025 V
	4.0 V	3.975 to 4.025 V
	3.0 V	2.975 to 3.025 V
	2.0 V	1.975 to 2.025 V
	1.0 V	0.975 to 1.025 V
*100 V	90.0 V	89.75 to 90.25 V
**1000 V	900.0 V	905.0 to 915.0 V

*Move connections to Instrument Calibration Standard Volts terminals.

**Move connections to Instrument Calibration Standard high voltage terminals.

4.1.5 Disconnect all equipment.

4.2 AC VOLTAGE CALIBRATION:

4.2.1 Set up AC Voltage Standard to produce AC Volts @ 400 Hz.

4.2.2 Set Test Instrument MODE switch to AC.

4.2.3 Connect equipment as shown in Figure 1.

4.2.4 Set AC Voltage Standard TRANSFER switch to OPERATE and rotate dials to 10.0 Volts.

4.2.5 Set Test Instrument RANGE switch to each position listed in Table 3, set AC Voltage Divider dials to each value listed in Table 3. The Test Instrument must indicate within the corresponding limits.

NOTE

RECORD TEST INSTRUMENT COUNTER INDICATION FOR EACH RANGE.

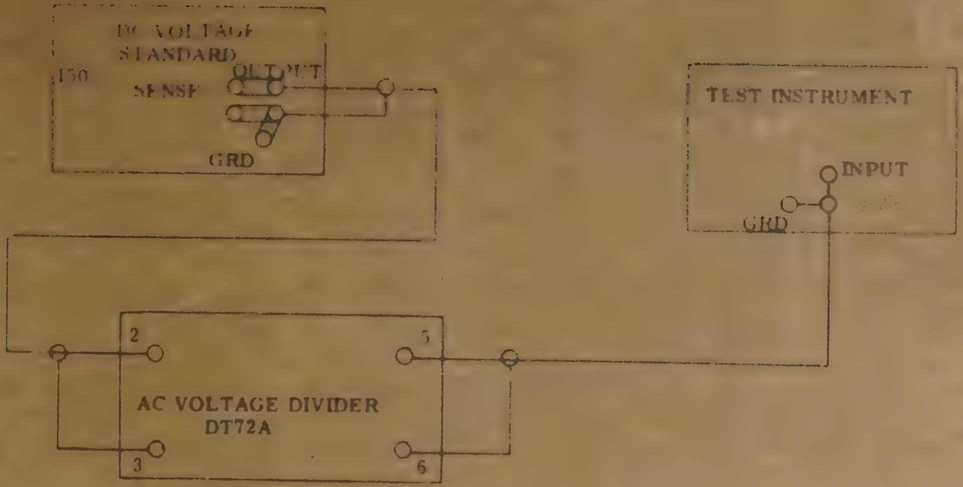


Figure 1

Table 3

Test Instrument Range	AC Voltage Divider	Test Instrument Limits
10 MV	.0009000	8.975 to 9.025 MV
100 MV	.0090000	89.75 to 90.25 MV

4.2.6 Set Test Instrument RANGE switch to 1 VOLT.

4.2.7 Set AC Voltage Divider dials to .0900000.

4.2.8 Set AC Voltage Standard FREQUENCY switch to 50 Hz, 400 Hz, 10 KHz, and record 400 Hz counter indication.

4.2.9 The Test Instrument must indicate within 0.8975 to 0.9025 Volts at each frequency.

4.2.10 Set AC Voltage Standard TRANSFER switch to STANDBY.

4.2.11 Disconnect all equipment.

4.2.12 Connect Test Instrument Input jack to AC Voltage Standard SENSE-OUTPUT terminals.

4.2.13 Set AC Voltage Standard TRANSFER switch to OPERATE.

4.2.14 Set Test Instrument RANGE switch to each position listed in Table 4, adjust AC Voltage Standard dials and FREQUENCY [illegible]. The Test Instrument must indicate within [illegible].

Table 4

Range	Applied	Limits
10 V	9.0 V @ 50 Hz, 400 Hz, 10 KHz	8.975 to 9.025 V
	*3.0 V @ 50 Hz, 400 Hz, 10 KHz	2.975 to 3.025 V
100 V	90.0 V @ 50 Hz, 400 Hz, 10 KHz	89.75 to 90.25 V
1000 V	900.0 V @ 50 Hz, 400 Hz, 10 KHz	905.0 to 915.0 V

*Record counter indication at 400 Hz.

4.2.15 Repeat step 4.2.10 and 4.2.11.

4.2.16 Connect Oscillator OUTPUT terminals to Frequency Response Test Set INPUT jack.

4.2.17 Set up Oscillator for 400 Hz.

4.2.18 Set up Frequency Response Test Set for 400 Hz operation.

4.2.19 Connect Test Instrument Input jack to Frequency Response Test Set OUTPUT jack.

4.2.20 Set Test Instrument RANGE switch to 10 Volts.

4.2.21 Set Frequency Response Test Set ATTENUATOR switch to 3 VOLTS, adjust Oscillator AMPLITUDE control for Test Instrument Counter indication recorded for 3 Volts in Table 4.

4.2.22 Adjust Frequency Response Test Set METER SET control for SET LEVEL indication on OUTPUT METER.

4.2.23 Set up Oscillator for 30 Hz.

4.2.24 Adjust Oscillator AMPLITUDE control for SET LEVEL indication on Frequency Response Test Set Meter.

4.2.25 The Test Instrument must indicate within 2.95 to 3.05 Volts.

4.2.26 Set up Oscillator for 50 KHz, and repeat step 4.2.24.

4.2.27 The Test Instrument must indicate within 2.95 to 3.05 Volts.

4.2.28 Set up Oscillator for 250 KHz, and repeat step 4.2.24.

4.2.29 The Test Instrument must indicate within 2.9 to 3.1 Volts.

4.2.30 Set up Oscillator for 400 Hz.

4.2.31 Set Test Instrument RANGE switch to 1 VOLT.

4.2.32 Set Frequency Response Test Set ATTENUATOR switch to 1 volt, adjust Oscillator AMPLITUDE control for Test Instrument Counter indication recorded for 0.9 Volts in step 4.2.8, and repeat step 4.2.22.

4.2.33 Set up Oscillator for 30 Hz and 50 KHz, and repeat step 4.2.24.

4.2.34 The Test Instrument must indicate within 0.895 to 0.905 Volts at each frequency.

4.2.35 Set up Oscillator for 250 KHz, and repeat step 4.2.24.

4.2.36 The Test Instrument must indicate within 0.89 to 0.91 Volts.

4.2.37 Set up Oscillator for 400 Hz.

4.2.38 Set Test Instrument RANGE switch to 100 MV.

4.2.39 Set Frequency Response Test Set ATTENUATOR switch to .1 Volt, adjust Oscillator AMPLITUDE control for Test Instrument Counter indication recorded in Table 3, and repeat step 4.2.22.

4.2.40 Set up Oscillator for 30 Hz and 50 KHz, and repeat step 4.2.24.

4.2.41 The Test Instrument must indicate within 89.5 to 90.5 MV at each frequency.

4.2.42 Set up Oscillator for 250 KHz, and repeat step 4.2.24.

4.2.43 The Test Instrument must indicate within 89.0 to 91.0 MV.

4.2.44 Set up Oscillator for 400 Hz.

4.2.45 Set Test Instrument RANGE switch to 10 MV.

4.2.46 Set Freouency Response Test Set ATTENAUTOR switch to .01 volt, adjust Oscillator AMPLITUDE control for Test Instrument Counter indication recorded in Table 3, and repeat step 4.2.22.

4.2.47 Set up Oscillator for 30 Hz and 50 KHz, and repeat step 4.2.24.

4.2.48 The Test Instrument must indicate within 8.95 to 9.05 MV at each frequency.

4.2.49 Set up Oscillator for 250 KHz, and repeat step 4.2.24.

4.2.50 The Test Instrument must indicate within 8.9 to 9.1 MV.

4.2.51 Disconnect and secure all equipment.

CALIBRATION PERFORMANCE TABLE

Range	Applied	Limits
DC Voltage Calibration:		
0 to 100 MV	90.0 MV	89.75 to 90.25 MV
0 to 1 V	0.9 V	0.8975 to 0.9025 V
0 to 10 V	9.0 V	8.975 to 9.025 V
	8.0 V	7.975 to 8.025 V
	7.0 V	6.975 to 7.025 V

"Continued on Page 7"

[illegible] PERFORMANCE TABLE CONT'D

[illegible]	Applied	Limits
DC Voltage Calibration (Continued)		
0 to 10 V	6.0 V	5.975 to 6.025 V
	5.0 V	4.975 to 5.025 V
	4.0 V	3.975 to 4.025 V
	3.0 V	2.975 to 3.025 V
	2.0 V	1.975 to 2.025 V
	1.0 V	0.975 to 1.025 V
0 to 100 V	90.0 V	89.75 to 90.25 V
0 to 1000 V	900.0 V	905.0 to 915.0 V
AC Voltage Calibration		
0 to 10 MV	9.0 MV @ 30Hz, 50KHz	8.95 to 9.05 MV
	9.0 MV @ 400Hz	8.975 to 9.025 MV
	9.0 MV @ 250KHz	8.9 to 9.1 MV
0 to 100 MV	90.0 MV @ 30Hz, 50KHz	89.5 to 90.5 MV
	90.0 MV @ 400Hz	89.75 to 90.25 MV
	90.0 MV @ 250KHz	89.0 to 91.0 MV
0 to 1 V	0.9 MV @ 30Hz, 50KHz	0.895 to 0.905 V
	0.9 MV @ 400Hz	0.8975 to 0.9025 V
	0.9 MV @ 250KHz	0.89 to 0.91 V
0 to 10 V	9.0V @ 50Hz, 400Hz, 10KHz	8.975 to 9.025 V
	3.0V @ 50Hz, 400Hz, 10KHz	2.975 to 3.025 V
	3.0V @ 30Hz, 50KHz	2.95 to 3.05 V
	3.0V @ 250KHz	2.9 to 3.1 V
0 to 100 V	90.0V @ 50Hz, 400Hz, 10KHz	89.75 to 90.25 V
0 to 1000 V	900.0V @ 50Hz, 400Hz, 10KHz	905.0 to 915.0 V

9